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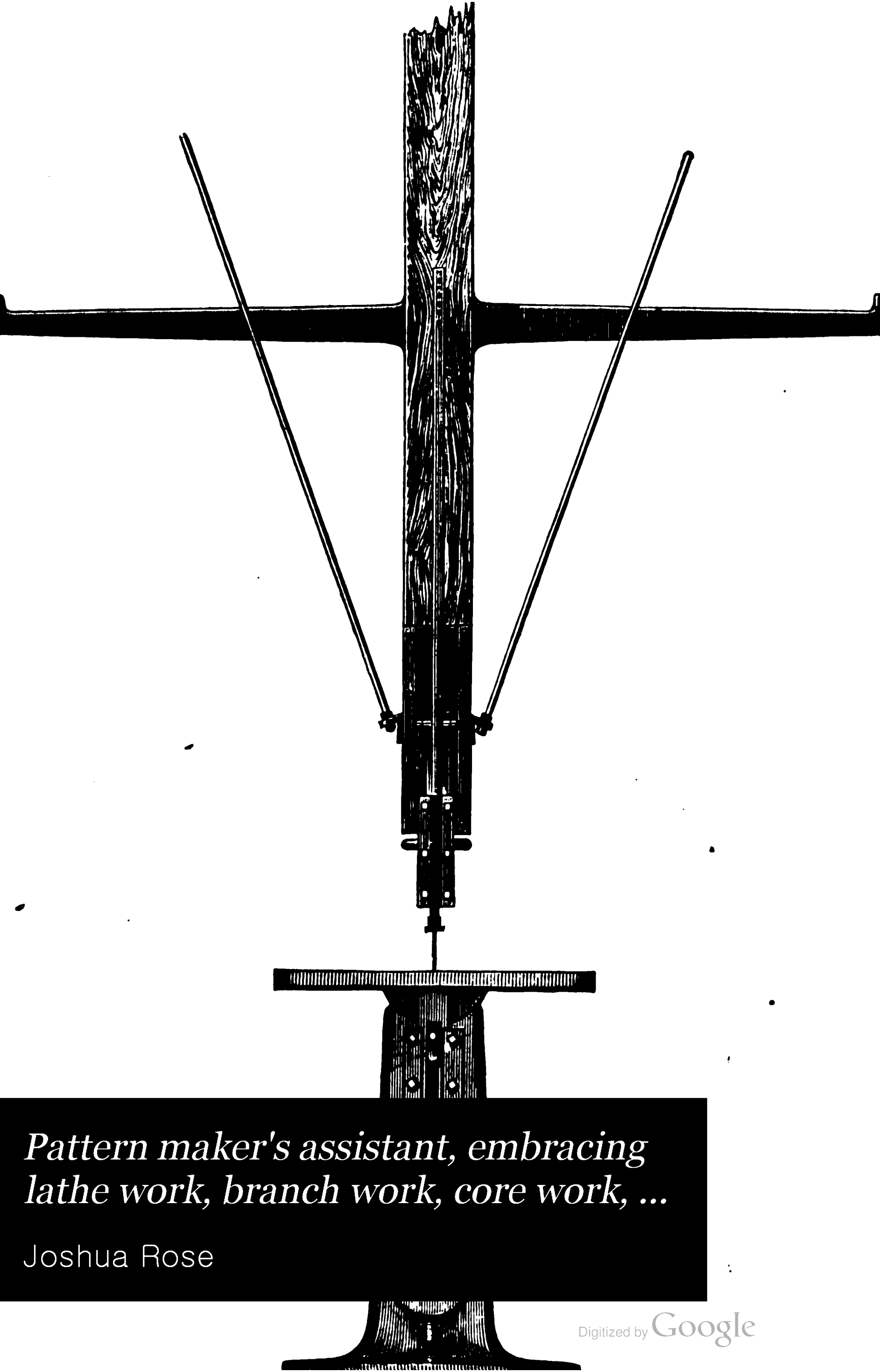

Pattern maker's assistant, embracing lathe work, branch work, core work, ...

Joshua Rose

Edward Stevens

Edward Knowles

HARVARD COLLEGE
July 22, 1941
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PREFACE.

THE object of this book is to impart a knowledge of Pattern Making that shall be useful to apprentice Pattern Makers, and also to practical machinists, because the drawings of the designer do not as a rule give any instructions as to the construction of the patterns, while at the same time that construction may affect to a considerable degree, the manipulations of the machinist.

Furthermore, it often occurs in the experience of a general machinist, that he is required to make a pattern either in iron or wood, and the complete isolation which usually exists between the pattern shop and the machine shop, is an effective bar to the acquisition of knowledge by observation.

The information is given from actual pattern shop practice, and in the ordinary workshop parlance.

The tables have been selected with a view to a collection comprising all that the Pattern Maker of the widest experience requires; arranged for his convenience, although in as compact a form as possible.

CONTENTS.

CHAPTER I.

PAGE.

General Remarks, - - - - - - 11
Selection of Wood, - - - - - - 15
Warping of Wood, - - - - - 17
Drying of Wood, - - - - - - 18
Plane-irons, - - - - - - 20
Grinding Plane-irons, - - - - - - 21
Descriptions of Planes, - - - - - 24
Chisels, - - - - - - - - 33
Gouges, - - - - - - - 36
Compasses, - - - - - - - 38
Squares, - - - - - - - 39
Gages, - - - - - - - 42
Trammels, - - - - - - 44
Winding-strips, - - - - - - 45
Screw-driver, - - - - - - 47
Mallet, - - - - - - - 48
Calipers, - - - - - - - 49

CHAPTER II.

Lathe, - - - - - - - 51
Lathe Hand-rest, - - - - - - 51
Lathe Head, - - - - - - - 54
Lathe Tail-stock, - - - - - - 56
Lathe Fork, - - - - - - - 57
Lathe Chucks, - - - - - 58
Gouge, - - - - - - - - 66
Skew-chisel, - - - - - - - 68
Turning Tools, - - - - - - 70

CHAPTER III.

Molding Flask, - - - - - - 73
How a Pattern is Molded, - - - - - 74
Snap Flash, - - - - - - 76

CHAPTER IV.

PAGE.
Description of Cores, ... 82
Core-boxes, ... 84
Examples of Cores, ... 86
Swept Core for Pipes, etc., ... 89

CHAPTER V.

Solid Gland Pattern, ... 92
Molding Solid Gland Pattern, ... 93
Gland Pattern without Core-print, . . . 95
Gland Pattern made in Halves, ... 97
Bearing, or Brass Pattern, ... 99
Rapping Patterns, ... 100
Example in Turning, ... 102
Sand-papering, ... 104
Pattern Pegs, ... 107
Pattern Dog, or Staple, ... 110
Varnishing, ... 112
Hexagon Gage, ... 115
Scriber, ... 118

CHAPTER VI.

Example in T-joints, or Branch Pipes, . . . 120
Example in Angular Branch Pipes, ... 126
Core-box for Branch Pipes, ... 130

CHAPTER VII.

Double-flanged Pulley, ... 132
Molding Double-flange Pulley, ... 132
Building up Patterns, ... 134
Shooting-board, ... 137
Jointing Spokes, ... 140

CHAPTER VIII.

Pipe Bend, ... 143
Core-Box for Pipe Bend, ... 147
Swept Core for Pipe Bend, ... 150
Staving, or Lagging, ... 151
Lagging Steam Pipes, ... 156

CHAPTER IX. PAGE.

Globe Valve, - - - - - - 158
Chucking Globe Valve, - - - - - 161
Core-boxes for Globe Valve, - - - - 162

CHAPTER X.

Bench, and Bench-stop, - - - - - 166
Bench-hook, - - - - - - 167
Mortise and Tenon, - - - - - - 167
Half-lap Joint, - - - - - - 168
Dovetail Joint, - - - - - - 168
Mitre-box, - - - - - - - 170
Pillow Block, - - - - - - 170

CHAPTER XI.

Square Column, - - - - - - 178
Block for Square Column, - - - - - 179
Ornaments for Square Column, - - - - 181
Cores for Square Columns, - - - - - 182
Patterns for Round Columns, - - - - 184

CHAPTER XII.

Thin Work, - - - - - - - 189
Window Sill, - - - - - - 189
Blocks for Window Sill, - - - - - 190

CHAPTER XIII.

Sweep and Loam-work, - - - - - 193
Sweeping up a Boiler, - - - - - 193
Sweep Spindle, - - - - - - 194
Sweeping up an Engine Cylinder, - - - - 197

CHAPTER XIV.

Gear-wheels, - - - - - - 199
Construction of Pinion, - - - - - 200
Construction of Wheel-teeth, - - - - 202
Gage for Wheel-teeth, - - - - - 202
Bevel Wheels, - - - - - - 206
Building up Bevel-wheels, - - - - - 211

CHAPTER XIV.—Continued. PAGE.

Worm Patterns, - - - - - - 213
Turning-screw of Worm Pattern, - - - - 213
Cutting Worm by Hand, - - - - - 216
Wheel Scale, - - - - - - - 218

CHAPTER XV.

Patterns for Pulleys, - - - - - 221
Section Patterns, - - - - - - 222

CHAPTER XVI.

Cogging, - - - - - - - 225
Woods Used for Cogging, - - - - - 226
Templates for Cog-teeth, - - - - - 227
Sawing Out Cogged Teeth, - - - - - 228
Boring Cogged Teeth, - - - - - 231

CHAPTER XVII.

Machine Tools for Pattern Making, - - - - 234
Face Lathe, - - - - - - 236
Jig Saw, - - - - - - - 237
Band Saw, - - - - - - - 240
Circular Saw, - - - - - - - 241
Planing Machine, - - - - - 242
Glue Pot, - - - - - - - 243

CHAPTER XVIII.

Shrinkage of Solid Cylinders, - - - - 244
" Globes, - - - - - - 244
" Disks, - - - - - - 245
" Round Square Bars, - - - - 245
" Rectangular Tubes, - - - 245
" U-shaped Castings, - - - - 246
" Wedge-shaped Castings, - - - 246
" Ribs on Plates, - - - - - 246
General Laws of Shrinkage, - - - - 246
Table of Shrinkage, - - - - - - 247
Calculating Thickness of Thin Pipes, - - - 248
Calculating Thickness of Cylinders for Hydraulic Presses, 249
Calculating Rims of Fly-wheels, - - - - 249

TABLES OF USEFUL INFORMATION.

PAGE.
Mixtures of Metals, 250
Melting Points of Metals, 250
Weight of Patterns and Castings, 251
Weight of Timber, 251
" Cast Metals, 251
Weight of a Lineal Foot of Flat Cast Iron, 255
Weight and Strength of Ropes and Chains, 255
Weight of Wire per Lineal Foot, 257
Weight of Metal Plates per Square Foot, 258
Weight of Water in Pipes, 259
Measures of Length, 260
Square Measure, 261
Solid, or Cubic Measure, 261
Avoirdupois Weight, 262
Troy Weight, 262
Ale and Beer Measure, 263
Wine Measure, 263
Foreign Measures of Length, compared with United States, 264
French Measures of Length, 265
Conversion of English Inches into Centimetres, 265
" Centimetres into English Inches, 266
" English Feet into Metres, 266
" Metres into English Feet, 266
" French Measure in United States, 267
Decimal Equivalents for Avoirdupois Weight, 268
" " Troy " 268
" " Long Measure, 268
Weight of Water in Decimal Equivalents, 269
" " at Different Temperatures, 269
Diametral Pitch, 270
Sizes of Paper, 271
" Sheet Iron and Zinc, 271
" Penny Nails, 271

TABLES OF USEFUL INFORMATION.—Continued. PAGE.

Sizes of Tapping-holes, - - - - - - 272
" Taps for Machine Screws, - - - - - 272
" Iron Washers, - - - - - - 273
" Iron Wire Rope, - - - - - - 273
Tables of Diameters, Circumferences, and Scale of Equal Squares, - - - - - - - 274
Tables of Squares, Cubes, Square Roots and Cube Roots of Numbers, - - - - - - - 284
Tables of Diameters, Circumferences and Areas of Circles, and the Contents in Gallons, at a foot in depth, - 297
Tables of Decimal Equivalents, - - - - - 300
Conversion of Vulgar Fractions into Decimals, - - 300
" Fractions of an Inch into Decimals of a Foot, 301
" Inches and Fractions into Decimals of a Foot, 301
" Inches into Decimals of a Yard, - - 301
Decimal Equivalents of Pounds and Ounces Avoirdupois, 301
Scantling and Timber Measure, - - - - - 302
To find the Chordial Pitch of Teeth, - - - - - 307
Table of the Radii, Number of Teeth, and Pitch of Gear Wheels, from ¼ to 1 inch Pitch, - - - - 308
Table of the Radii, Number of Teeth, and Pitch of Gear Wheels, from 1¼ to 3 inches Pitch, - - - 314

THE PATTERN MAKER'S ASSISTANT.

CHAPTER I.

PATTERN MAKING.

THOSE savans who have read our old earth's unwritten history in and from its strata, tell us that, in ages far remote, men made tools and contrivances of bronze, which, being an alloy, necessitated the fusion and casting of the metal. This casting involves the use of patterns, and pattern making may therefore lay claim to the highest antiquity. But the modern idea of the division of labor has exalted it to be a distinctive art; in the last generation, for instance, a good machinist (or rather engineer or millwright, for those terms were then applied to builders of machinery,) was required to be alike expert in working upon both wood and metal. He constructed his framing of wood, and made the patterns for his cast metal work; he was to-day a lathe hand, to-morrow a vise hand.

As, however, the present age of iron dawned, it became apparent that working in wood and in metal must be separated, not only because the handiwork could be more cheaply produced by reason of the increased skill arising from continuous practice, but also because the amount of knowledge required to make an artisan skillful in either the manufacture of wood or of iron, was too great to be thoroughly mastered in the working lifetime of an ordinary, or even an unusually expert workman. Hence modern intelligence soon discovered that better as well as cheaper work could be obtained by a practical education in one particular branch of usefulness, and hence pattern making has taken its place as a specialty. The field of usefulness of cast iron has developed to a remarkable extent during the last twenty years, and the same remark applies to cast steel during the last ten years; both of these materials are steadily encroaching upon the domain of usefulness of wrought iron, stone, and bricks and mortar. So that the field of application for pattern making is stretching outward and onward, to the discomfiture of its rivals. From these considerations, we may readily perceive that a real proficiency in pattern making will exercise to the utmost the skill of the workman, on account of the unceasing variety of the patterns, in form and in the purposes for which they are designed; and the advantage of a retentive memory is evident when we consider that years may elapse ere the same pattern maker may be called upon to exercise his skill upon the same or a similar piece of work. In this art, there are to be considered many details that are seldom or never shown in drawings; such, for instance, as the amount necessary to allow on the pattern for finishing certain parts of a casting, and on what part such allowance is required; and the method which has been proved by experience to be the safest and most expeditious in molding from a certain kind of pattern. But above all these considerations lies the fact that drawings merely show the shape which the finished pattern is required to have, leaving it entirely to the judgment of the pattern maker to elect in what way the various pieces of wood (of which the pattern is constructed) shall have the grain lie, and how they shall be fastened or held together. There is, it is true, an unwritten practice which has obtained universal observance in particular branches of pattern making; but in the newer fields into which the art has advanced and is advancing, this unwritten practice is merely in the process of formation, which state of things must continue so long as casting is discovered to have new arenas of application. A goodly store of well remembered experience is therefore invaluable to the pattern maker; and this being so, the quicker it is obtained the better. Hence the learner should always keep a record of the work which falls under his observation, in which record the sizes and proportions of the work, the method of putting it together, the time taken in its production, and (if possible) whether the castings were satisfactory, noting the defects in the latter, if any, together with suggestions for the remedy of those defects. A pen and ink sketch of the pattern made in the margin will add to the usefulness of the record, besides accustoming the hand to making correct sketches and elucidating the explanation. The operative's intelligence will be much exercised in the shaping and building-up of patterns, depending as this does on the strength of the material of which the casting is to be made, the strength of the pattern itself, and the desirability of its molding well. Dr. Andrews has well said (in the *English Mechanic*): "The correct forms to be given to the materials employed in the construction of tools or machinery depend entirely upon natural principles. Natural form consists in giving to each part the exact proportion that will enable it to fulfill its assigned duty with the smallest expenditure of material, and in placing each portion of the materials under the most favorable conditions of position that the circumstances will admit of. Such natural form is not only the most economical, but, strange to say, it is always correct in every respect, and is invariably beautiful and lovely in its outlines."

I may now mention the qualifications necessary to enable an artisan to become a good pattern maker: First: As the idea of the size and contour of the article or work required will be conveyed to him by drawings, it is necessary that he should be conversant with the principles of mechanical and architectural drawing; and it may be of great advantage to him, though it is not absolutely necessary, to be able to make such drawings. It is too often the case that the apprentice pattern maker gains his knowledge of drawing from the drawings from which he operates, which, being simple in the first case, and becoming complicated only after the lapse of two or three years, makes the acquisition of a knowledge of drawing possible without either study or application; but the result is that, so soon as he is called upon in a new field of action, upon a description of work different from that to which he has been accustomed, he becomes timid, gets confused, finds it necessary to ask many questions upon and concerning various parts of the drawings, and then does not obtain credit for the amount of ability to which his skill in handling his tools perhaps entitles him. Furthermore, a knowledge of drawing will enable him to learn his trade in a comparatively short space of time, and give him confidence in, and a retention of, that which he has already learned. Secondly: He should be perfectly familiar with the operations of the brass and iron founder, as it is by him that patterns will be used to produce the required forms. The pattern must be so made that a mold can be made from it, and that it may be made in the most expeditious manner. The pattern maker, it must be remembered, determines how the molder is to mold the pattern, so that the latter is controlled in his operations by the former. For the benefit of those who have been unable to devote sufficient time to the work of the foundery, it will be necessary, as we proceed, to explain the operations of molding different kinds of patterns, selecting those which will best serve as a key to the whole. Thirdly: The pattern maker must be acquainted with some, at least, of the properties of the metals of which the castings from his patterns are to be made; such, for instance, as how they behave in passing from the fluid, to the solid state, the strains to which a casting is subject during this transition, to what extent those strains may be modified by alterations of proportion or shape in the pattern, the shrinkage of castings, and the alteration in form which takes place in the cooling of castings of various sizes and shapes. Fourthly: He should, if possible, add to the above qualifications a general knowledge of the manner of fitting up the different kinds of work for which patterns are used.

With regard to the first requirement, it is not my purpose to enter into the subject of mechanical drawing, which is treated of in books devoted exclusively to that subject. With regard to the second, I shall, as already stated, refer to it hereafter. The third I shall consider after I have treated upon timber, and tools; and the fourth can only be obtained by watchfulness on the part of the student as to what is being done in the workshop in which he is engaged. This latter may seem a trivial matter; but I have on several occasions, by watching where certain castings required to be most operated upon in the machine or vise, had a pattern altered, making it apparently of an incorrect form, with the result that the time necessary to fit the work was reduced by one half. This subject, however, will be treated upon in its proper place.

Of the different kinds of wood serviceable to the pattern maker, pine is, for many reasons, usually employed. It should be of the best quality, straight-grained, and free from knots; it is then easy to work in any direction, possessing at the same time sufficient strength for all but the most delicate kinds of work, and having besides the quality of cheapness to recommend it. Care taken in its selection at the lumber yard will be amply repaid in the workshop. When it is straight-grained, the marks left by the saw will show an even roughness throughout the whole length of the plank;

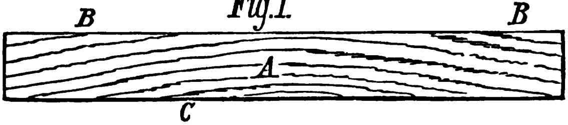
and the rougher the appearance, the softer the plank. That which is sawn comparatively smooth will be found hard and troublesome to work. If the plank has an uneven appearance—that is to say, if it is rough in some parts and smooth in others—the grain is crooked. Such timber is known to the trade as catfaced. In planing it, the grain tears up, and a nice smooth surface cannot be obtained. Before purchasing timber, it is well to note, what convenience the yard possesses for storing. Lumber on the pile, though it be out in all weathers, does not deteriorate, but becomes seasoned; nevertheless its value is much increased if it has an extemporized roof to protect it from the sun and rain; but as it is not convenient to visit the pile for every customer, quantities are usually taken down to await sale, and for such, a shelter must be provided, otherwise it will be impossible to insure that the lumber is dry, sound, and fit for pattern making; it being obvious that the foregoing remarks on the storage of lumber apply to all woods.

The superiority of pine for pattern making is not, however, maintained when we come to fine delicate patterns or patterns requiring great durability. When patterns for fine work, from which a great many castings are to be made, are required, a pattern wherefrom to cast an iron pattern is improvised, because, if pine were employed, it would not only become rapidly worn out, but would soon warp and become useless. It is true that a pine pattern will straighten more easily than one made of a hard wood; but its sphere of usefulness in fine patterns is, for the above reasons, somewhat limited. Iron patterns are very desirable on account of their durability, and because they leave the sand easily and cleanly, and because they not only do not warp, but are also less liable than wooden ones to give way to the sand, while the latter is being rammed around them by the molder—a defect that is often experienced with light patterns, especially if they are made of pine. Iron patterns, however, are expensive things to make, and therefore it is that mahogany is extensively employed for fine or durable pattern work. Other woods are sometimes employed, because they stand the rough usage of the molding shop better and retain the sharp corners, which, if pine be used, in time become rounded, impairing the appearance of the casting. Mahogany is not liable to warp, nor subject to decay; and is for these reasons the most desirable of all woods employed in pattern making, providing that first cost is not a primary consideration. There are various kinds of this beautiful wood, that known as South American mahogany being chiefly used for patterns.

Next to mahogany we may rank cherry, which is a very durable wood, but more liable to twist or warp than mahogany, and it is a little harsh to the tool edge. If, however, it is stored in the workshop for a length of time before being used, reliable patterns may be made from it. In addition to these woods, walnut, beech, and teak are sometimes employed in pattern making.

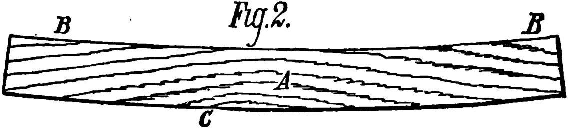
The one property in all timber to be specially guarded against is its tendency to warp, bend, expand, and contract, according to the amount of humidity in the atmosphere. Under ordinary conditions, we shall be right in supposing a moisture to be constantly given off from all the exposed surfaces of timber; therefore planks stored in the shop should be placed in a rack so contrived that they do not touch one another, so that the air may circulate between the planks, and dry all surfaces as nearly alike as possible. If a plank newly planed be lying on the bench on its flat side, the moisture will be given off freely from the upper surface, but will, on the under surface, be confined between the bench and the plank: the result being that a plank, planed straight and left lying as described, will be found, even in an hour, to be curved, from the contraction of the upper surface due to its extra exposure; and therefore it is that lumber newly planed should be stored on end or placed on edge. Lumber expands and contracts with considerable force across the grain; hence if a piece even of a dry plank, be rigidly held and confined at the edges, it will shrink and rend in twain, often with a loud report. There is no appreciable alteration lengthwise in timber from the above causes; and if two pieces be glued together so that the grain of one crosses that of the other, they can never safely be relied upon to hold. Hence they had better be screwed, so that there will be a little liberty for the operation or play of the above forces, while the screws retain their hold. The shrinkage, expansion, and warping of timber may perhaps be better understood by considering as follows: The pores of wood run lengthwise, or with its grain, and hence the moisture contained in these passes off more readily endwise or from any surface on which the pores terminate. Then again the wood shrinks precisely in proportion in which the moisture leaves it; and if we have full knowledge of the direction of the grain, and of the position in which a piece of timber stands or lies, we can (all other things being equal, that is to say, supposing there to be no artificial heat or other disturbing cause operating on one more than on another side of it) predicate in what direction it will warp. Thus, let A, Fig. 1, be a piece of timber having the direction

Fig. 1



of its grain as denoted by the lines; then its surface, B B, which has the grain and pores terminating upon it, would allow free exit of the moisture, and that face would dry first (especially if it lay uppermost) and w[illegible] corners, A B, are so that after a time the shape of the pi[illegible] The beveled face as shown in Fig. 2. Now if it had been placed to lay with the face, C, uppermost, the warping would have been much less, because the extra porosity of the face, B B, would have been counteracted by the lack of circulation of air. If, on the other hand, it was placed endwise, the warping, though it would have taken place, would have been appreciably less. It must not be supposed that thoroughly seasoning the timber will remove the tendency to warp, for timber, however long and carefully it has been dried or seasoned, undergoes considerable transformation of shape so soon as much of its outer surface is removed, making it appear that the seasoning or drying process takes place mainly at and near the outer surfaces, and is renewed every time an entirely new surface is presented to the action of the atmosphere. Thus, if we take a thoroughly seasoned piece of wood 3 inches square and 1 foot long, and cut it into strips 1 inch square and 1 foot long, the pieces will warp in a day or so; and if, after a few days, we take those inch strips and cut them into strips ¼ inch square and 1 foot long, these latter will again warp; and no matter what pains might be taken with these last strips to season them and let them assume their new shape, were we to cut them into thin veneers the warping process would again set in. It is well, therefore, in particular work, to cut out roughly the various parts of the pattern, so that, while some parts are being operated upon, the others may be assuming their new shape, and thus become not so liable to warp after being worked up in the pattern.

Fig. 2.



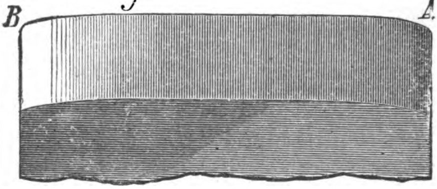
traction of the uppe
and therefore it is

TOOLS, ETC.

One of our first requisites in the way of tools and appliances will be a carpenter's bench, which may be made as follows: Three pieces of stuff, 2x5 inches and 3 feet long, will serve for supports for the top. Two 12 inch boards, 12 feet long and 1 inch thick, will do for the sides. Nail these side boards firmly to the 2x5 inch cross pieces, and put on a top of suitable material, and the bench is ready for the legs. Now take four pieces of stuff, 2x5 inches, and of the requisite hight for the legs, and frame a piece 1x3 inches across each pair of legs, about 6 inches from the bottom, placing the legs at the distance apart necessary for the width of the bench. Then cut a fork or slit in the top end of each leg, so as to straddle the cross piece at the ends, and put a bolt 3½x⅜ inches through each leg and through the side boards, and the bench will be complete; and it will possess the advantage that it can be taken down in a few minutes by removing the bolts from the legs.

The jack plane is employed for roughing off the surface timber; the stock is made of beech and the blade of cast steel. The blade acts most effectively when it is ground well away toward the corners, thus producing a curved edge, as shown in Fig. 3. When the blade is placed in the stock,

Fig. 3.



and in position to cut off the largest amount of stuff, its cutting edge should protrude through the face of the stock about a sixteenth of an inch, while the corners, A B, are about level with the face of the stock. The beveled face should stand at about an angle of 50° to the flat face. The grindstone should be kept true and liberally supplied with water; the straight face should not be ground away, nor indeed touched upon the stone. The pressure with which the blade is held against the grindstone should be slight at and toward the finishing part of the grinding process, so as not to leave a long ragged burr on the end of the blade, as is sure to be the case if much pressure is applied; and it will occur to a slight extent even with the greatest of care. The blade should not be held still upon the grindstone, no matter how true, flat, or smooth the latter may be; but it should be moved back and forth across the width of the stone, which will not only grind the blade bevel even and level, but will also tend to keep the grindstone in good order.

If a grindstone is in excellent condition (that is, true, flat, and level, or slightly rounding), as it should be, it tempts the workman to grind the plane blade with the stone running toward him, as shown in Fig. 4, for the following reasons: If the stone, A, travels in the direction of the arrow, C, the plane blade, B, will relieve the abrasion of the stone at the cutting edge first, thus leaving it clean and with no tendency to leave a long ragged edge; but if the blade were

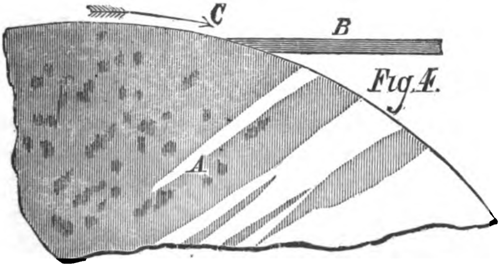
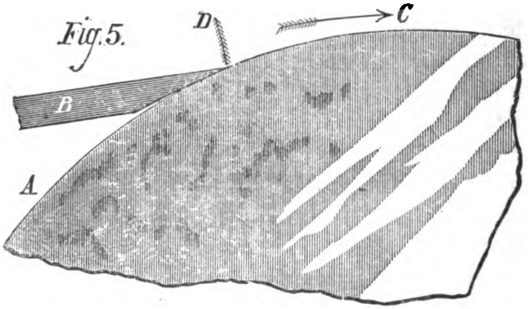


Fig. 4.

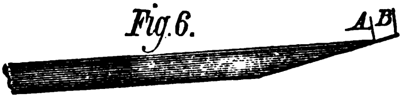
held on the other side of the stone, that is to say, with the stone running from the operator, as shown in Fig. 5, the result will be a long ragged edge on the plane blade, especially if much pressure be placed on the blade.

Fig. 5.



In Fig. 5, A represents the grindstone, B the plane blade, and C the direction in which the grindstone is supposed to revolve: in which case it becomes evident that the plane blade will receive at its edge some pressure in the direction of the arrow, D; and the metal at the cutting edge of the blade, being very thin, gives way to this pressure and bends back instead of abrading off, leaving a long feather edge, as shown in Fig. 6, from A to B. This edge breaks off in many cases further back than it should do, and inevitably breaks off when the blade is applied to the oilstone, leaving upon the face of the oilstone particles of steel which must be removed before a good edge can be secured to the tool. As a rule, however, this feather edge is broken off by tapping the blade on the palm of the hand, or it may

Fig. 6.



be removed by passing the edge lengthwise on a piece of wood. It is, however, better to hold the blade as shown in Fig. 4; but there are other considerations which sometimes render this impracticable. For instance, if the stone is out of true, the high spots will strike against the cutting edge, and render it impossible to hold the blade steadily, and hence impossible to grind it true. If the stone has soft spots in it, as most stones have, the blade will dig in those soft spots, and will also be thrown off the stone when encountering an unusually hard spot. If, in consequence of digging in a soft spot, the blade catches, the cutting edge will be ground completely off; so that it is only under exceptional and unusual circumstances that the blade can be ground in the position shown in Fig. 4. It is better, therefore, to grind it in the position shown in Fig. 5, which is safer and surer. In oilstoning a plane blade, the straight face should be held quite level with the face of the oilstone, so that the cutting edge may not be beveled off. Not much application to the oilstone is necessary to the straight face, because that face is not ground upon the grindstone, and it only requires to have the wire edge or burr removed, leaving an oilstone polish all along the cutting edge. The oilstoning should be performed alternately on the flat and beveled faces, the blade being pressed very lightly on the oilstone toward the last part of the operation, so as to leave as fine a wire edge as possible. The wire is the edge or burr which bends or turns over at the extreme edge of the tool, in consequence of that extreme edge giving way to the pressure of the abrading tool, be it a grindstone or an oilstone. This wire edge is reduced to a minimum by the oilstone, and is then so fine that it is practically of but little account; to remove it, however, the plane blade or iron may be buffed backwards and forwards on the palm of the hand.

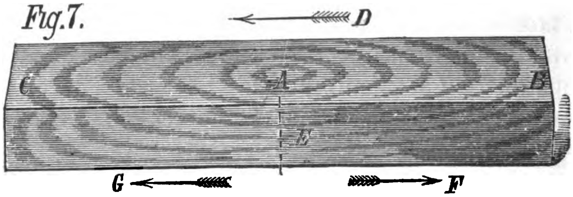
The iron being sharpened, we may screw the cover on, adjusting it so that its edge stands a shade below the corners of the iron, and then screwing it tight; the blade or iron and the cover must now be placed in the mouth of the plane stock, and adjusted in the following manner: The plane iron should be passed through the mouth of the stock until as much in depth of it is seen to protrude from the bottom face of the stock as is equal to the thickness of shaving it is intended to cut: to estimate which, place the back end of the plane upon the bench, holding the stock in the left hand with the thumb in the plane mouth, so as to retain the iron and wedge in position, the wedge being turned toward the workman. A glance down the face of the stock will be sufficient to inform the operator how much or how little the cutting edge of the iron protrudes from the face of the plane stock, and hence how thick his shaving will be. When the distance is adjusted as nearly as possible, the wedge may be tightened by a few light blows of the hammer. If, after tightening the wedge, the blade is found to protrude too much, a light blow on the fore end of the top face of the plane will cause it to retire. The wedge should be tightened by a light blow after it is finally adjusted.

In using a jack plane, we commence each stroke by exerting a pressure mostly on the fore part of the plane, commencing at the end and towards the edge of the board, and taking off a shaving as long as the arms can conveniently reach. If the board is longer than can be reached without moving, we pass across the board, planing it all across at one standing; then we step sufficiently forward, and carry the planing forward, repeating this until the jack planing is completed. To try the level of the board, the edge or corner of the plane may be employed; and if the plane is moved back and forth on the corner or edge, it will indent, and so point out the high place.

The fore plane (or truing plane, as it is sometimes called) is made large, so as to cover more surface, and therefore to cut more truly. It is ground and set in the same manner as the jack plane, with the exception that the corners of the iron or blade, for about one eighth inch only, should be ground to a very little below the level of the rest of the cutting edge, the latter being made perfectly straight (or as near so as practically attainable) and square with the edge of the iron. If the end edge of the cover is made square with the side edge, and the iron is ground with the cover on, the latter will form a guide whereby to grind the iron edge true and square; but in such case the cover should be set back so that there will be no danger of the grindstone touching it. The oilstoning should be performed in the manner described for the jack plane, bearing in mind that the object to be aimed at is to be able to make as broad and fine a shaving as possible without the corners of the plane iron digging into the work. The plane iron should be so set that its cutting edge can only just be seen projecting evenly through the stock. In using the fore or truing plane, it is usual, on the back stroke, to twist the body of the plane so that it will slide along the board on its edge, there being no contact between the cutting edge of the plane iron and the face of the board, which is to preserve the cutting edge of the plane iron from abrasion by the wood; as it is obvious that such abrasion would be much more destructive to the edge than the cutting duty performed during the front stroke would be. The face of the fore plane must be kept perfectly flat on the under side, which should be square with the sides of the plane. If the under side be hollow, the plane iron edge will have to protrude further through the plane face to compensate for the hollowness of the latter; and in that case it will be impossible to take fine shavings off thin stuff, because the blade or iron will protrude too much, and as a consequence there will be an unnecessary amount of labor incurred in setting and resetting the plane iron. The reason that the under surface should be square, that is to say, at a right angle to the sides of the body of the plane, is because the plane is sometimes used on its side on a shooting board.

When the under surface of the plane is worn out of true, let the iron be wedged in the plane mouth, but let the cutting edge of the iron be well below the surface of the plane stock. Then, with another fore plane, freshly sharpened and set very fine, true up the surface, and be sure the surface does not wind, which may be ascertained by the application of a pair of winding strips, the manner of applying which will be explained hereafter. If the mouth of a fore plane wears too wide, as it is apt in time to do, short little shavings, tightly curled up, will fall half in and half out of the mouth, and prevent the iron from cutting, and will cause it to leave scores in the work, entailing a great loss of time, in removing them at every few strokes. The smoothing plane is used for smoothing rather than truing work, and is made shorter than the truing plane, so as to be handier in using. It is sometimes impracticable to make a surface as smooth as desirable with a truing plane, because of the direction of the grain of the wood. Thus in Fig. 7, let E represent a piece of stuff requiring to be planed on

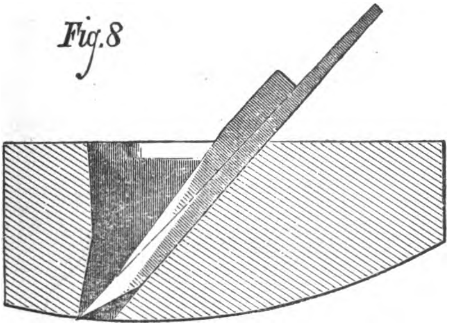
Fig. 7.



the upper surface, and let us plane it, cutting in the direction of the arrow, D. It is evident that the edge of the plane iron, when cutting the surface from B to A, will strike against the edge or end of the grain of the wood, tending to rough it up; whereas, while passing from A to C, the tendency of the pressure of the iron edge would be to smooth the grain of the wood downwards, the difference between the two tendencies being sufficient to make it necessary in many cases to use a smoothing plane, cutting in both directions, as shown in Fig. 7, first from A to B, cutting in the direction of the arrow, F, and then from A to C, cutting in the direction of the arrow, G. Thus the cutting will be at all times performed in the direction tending to smooth down and not rough up the grain of the wood. That this method of planing is necessary is demonstrated in planing across the end grain of wood, for which purpose the smoothing plane is almost indispensable, and in which operation it is necessary to use it, on small surfaces, with a side as well as with a forward sweep, thus producing a curved motion, the most desirable direction of which is determined by the direction of the grain of the wood.

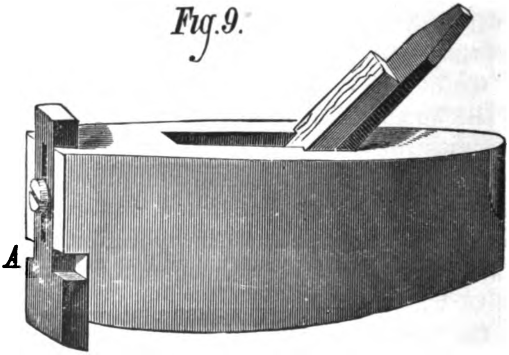
Fig. 8 represents an ordinary compass plane, which is a necessary and very useful tool for planing the surfaces of hollow sweeps. This tool is sometimes made adjustable by means of a piece dovetailed in the front end of the plane, as shown in Fig. 9, at A; which, by being lowered, alters the sweep and finally converts it from a convex to a concave. There is now, however, in the market a compass plane, the

Fig. 8



body of which is made of malleable iron with a sole made of a blade of spring steel, which, by the operation of two screws, can be set to any curvature, either concave or convex, within the capacity of the instrument.

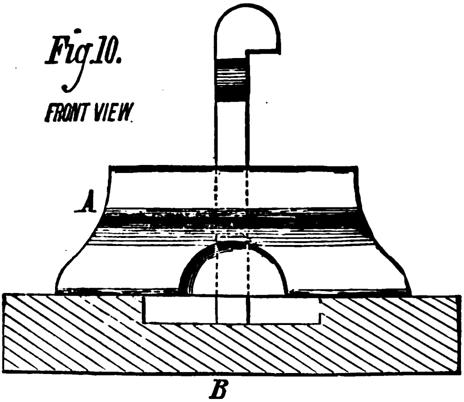
Fig. 9.



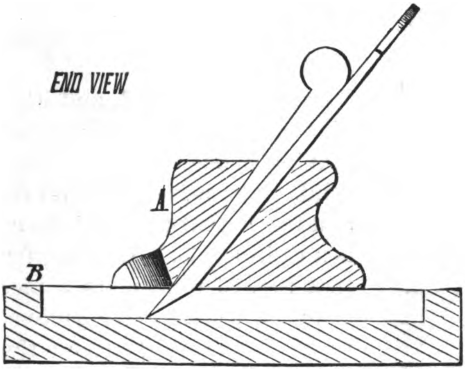
Another very useful species of plane is the router, shown in Fig. 10, which represents one of these planes in operation, A being the router, and B the work. The use of this tool is to plane out recesses (exactly to any given depth) such

Fig. 10.

FRONT VIEW.



as are required to receive rapping plates. The wood in the plane stock is cut away just over the edge of the iron, to give clearance for the shavings, and so that the cutter may be seen at work.



Rabbet planes are narrow planes having the sole or side of a conformation to suit the work. Fig. 11 represents a rabbet plane to suit a round edge, Fig. 12, a similar plane for a groove, and Fig. 13 a side rabbet plane. The latter is, however, very seldom used, but is especially useful in planing hard wood cogs fitted to iron wheels, or the teeth of wheel

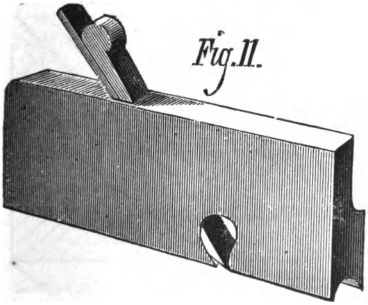


Fig. 11.

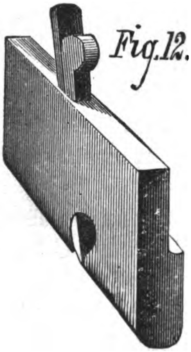


Fig. 12.

patterns, or other similar work. One or two flat bottomed ones will also be required. Small thumb rabbet planes, having an iron stock, with the blade near the front end, are now supplied, and are very useful for cutting out half checks that are not cut right across the stuff.

Fig.13.

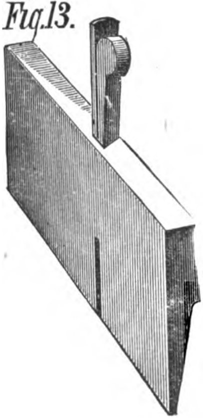


Fig. 14 is an end, and Fig. 15 a side, view of a core box plane, suitable for planing semicircular grooves out of the solid. The principle of its construction and use is that the angle in a semicircle is a right angle. Suppose, for example, that Fig. 16 represents a piece of wood having a semicircular groove in it, and we mark off on the groove the points, *a*, *b*, *c*, *d*, *e*, and strike from each of these a line direct to each corner of the groove. We shall thus find that the two lines struck will be at a right angle to each other, the two lines, A A, meeting at the point, *a*, being at a right angle. The two side faces, CC, of the plane in Fig. 14 are made to stand at a right angle to each other; and while the plane is in position (as shown in Fig. 14) to bear against the corners of the core

Fig.14.

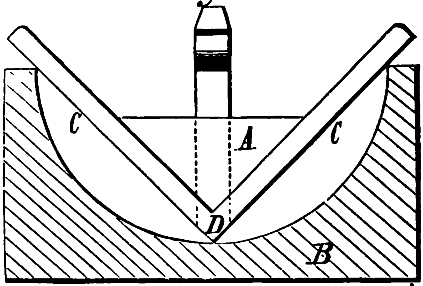
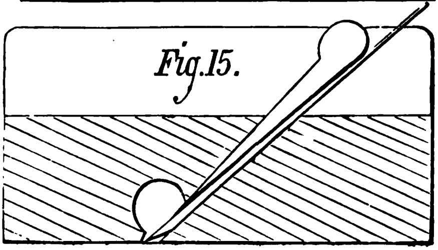


Fig.15.



box, a semicircle (the apex of the plane, D, in Fig. 14) must be in the semicircle, and will only cut away the wood in the form of the circle, no matter in what position the plane stands, so long as its sides touch the corners of the semicircle. This being the case, the first operation in using this plane is to cut out the required semicircle to the necessary width, which may be done with a rabbet plane. The core box plane may thus be employed to cut out the semicircle, commencing at each of the corners and planing on each side down to the center of the depth of the semicircle. As this plane is intended to finish the work, it is desirable to cut away as much of the stuff as possible before employing it, the work appearing as shown in Fig. 17. These planes have one disadvantage. They are apt

Fig.16.

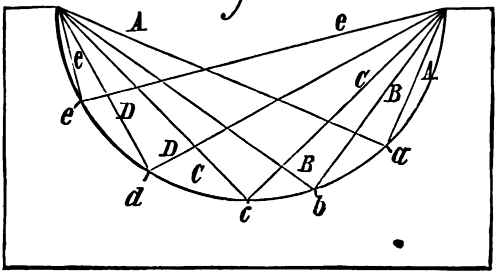
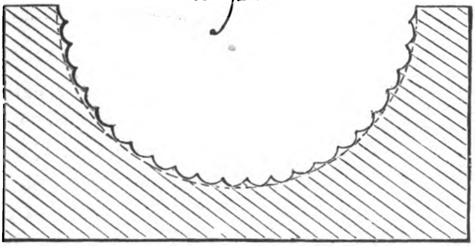


Fig.17.



to abrade the corners of the work; hence great care should be exercised in their use, and care must also be taken that the extreme point of the plane iron stands just at the apex of the angle of the body of the plane; for if it be in advance or not up to it, the work will not be semicircular.

Of late years there have been introduced planes having a stock of iron, the advantage being that the mouth does not wear larger, the soles keep true, and all parts are interchangeable. The blade of the block plane, shown in Fig. A, is set at a greater angle, as is necessary for planing the end grain of wood. The circular plane, shown in Fig. B, is an especially desirable tool, because the sole can be set to any desired curve, either concave or convex, and the plane can be used clear up to the edge of the curve; in which respect it possesses an advantage over the plane shown in Figs. 8 and 9.

Fig. A.

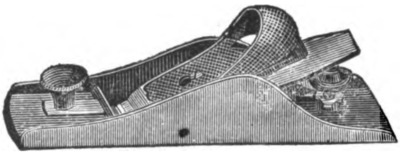


Fig. B.

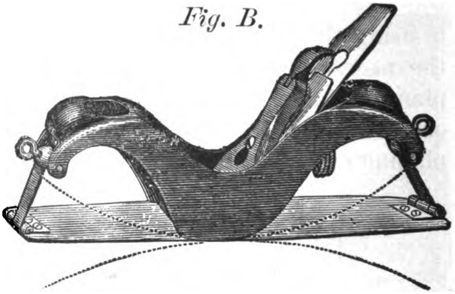
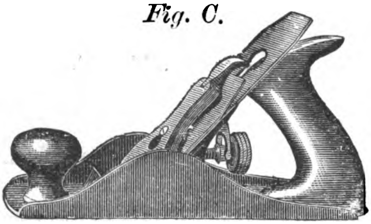


Fig. C.



In Figs. C and D are smoothing and jointer planes of this class; and it may be mentioned that the blades can be altered in adjustment while the plane is being operated. There is a sense of flatness in using these planes, that is very desirable for true work. The manner in which the iron fits to the blade is shown in Fig. E, the iron being

Fig. D

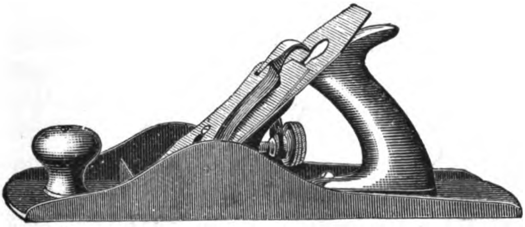
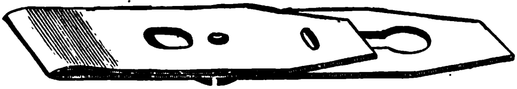


Fig. E.



curved to insure that it shall touch the blade close to the cutting edge, supporting and stiffening it so that thinner blades can be used, the latter being easier to grind and oilstone.

Of chisels, the principal kinds used are the paring chisel, used entirely by hand pressure, and the firmer chisel, for use with the mallet. The difference between the two is that the paring chisel is the longer. A paring chisel, worn to half its original length, will however answer for use as a firmer chisel, because, when so worn, it is sufficiently long for the duty. A chisel should not, however, be used indiscriminately as a paring and firmer chisel, for the reason that the paring chisel requires to be kept in much better order than the firmer chisel does. It is necessary to have several sizes of chisels, varying in width from an eighth of an inch to an inch and a half. A paring chisel for general use is shown in Fig. 18. Its width is about one and a half inch, and its handle should be exactly of the form shown in the engraving; the total length of handle being six inches, from A to B being one and a half inch, and the diameter at C, and from B upwards, being one and a half inch. The hollow below B is of three-eighths inch radius, and the diameter at D is one inch. This shape and size gives a good purchase, especially from A to B, where the hand is most often applied, the end, E, being against

Fig. 18.

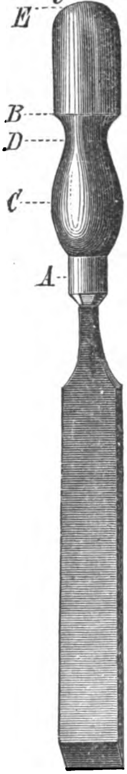
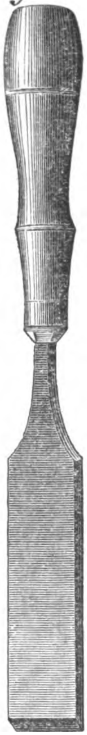


Fig. 19.



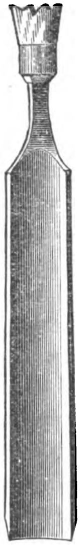
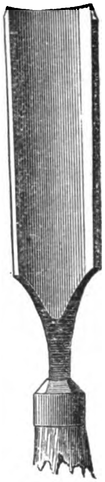


Fig. 20.

Fig. 21.



the operator's shoulder. A firmer chisel having a handle of the ordinary pattern is shown in Fig. 19.

Chisels are sharpened in the same manner as plane irons; but being usually narrower, they require special attention in the grinding, as they should be held against the grindstone with an amount of pressure proportionate to their width. In describing Figs. 5 and 6, it was explained how a long feather edge may be given to a tool in the grinding; and these remarks apply especially to chisels. Hence, towards the finishing part of the grinding operation, the chisel should be held very lightly against the stone; the flat face of the chisel should never be ground, but should be kept straight and even, otherwise the whole value of the tool will be impaired. In setting the edge of a chisel upon an oilstone, it is necessary to exercise great care that the hands are not elevated so as to oilstone the blade at a different bevel to that at which it was ground, and not to allow the movement of the hands to be such as to round off the bevel face at and near the cutting edge—an error which, from lack of experience, is very apt to occur. The position in which the bevel of the chisel should be pressed to the oilstone should be such that the marks made by the oilstone will lie from the back of the bevel to the cutting edge, but be shown more strongly at and towards the cutting edge. The motion of the hands of the operator should not be simply back and forth, parallel with the length of the oilstone, but partly diagonal, which will greatly assist in keeping the bevel level with the oilstone. Very little pressure should be applied to the chisel during the latter part of the process of oilstoning; and the flat face of the chisel should be held level with the face of the oilstone, and moved diagonally under a light pressure, sufficient only to remove the wire edge. After the setting is complete, the chisel should be lapped upon the hand, to remove the fine wire edge left by the oilstone.

The next tool is the gouge, of which there are several kinds. Those having the bevel on the concave side are termed inside gouges; and when the bevel is on the convex side, they are called outside gouges. Gouges, like chisels, are also classed into firmer and paring gouges, the distinction between the two being the same as in the case of chisels. It is not necessary to possess a full set of each kind of gouges; half a set each of inside and outside will suffice. Fig. 20 represents a paring, and Fig. 21 a firmer, outside gouge.

The inside gouge may be ground a little keener than the chisel or plane iron, and requires care in the operation, since it has generally to be ground on the corner of the grindstone, which is rarely of the same curve as the gouge requires. In oilstoning a gouge, what is called a slip is employed. Slips are wedge-shaped pieces of oilstone, of various curves and shapes, to suit the purposes for which they are applied. The gouge should be held in the left hand, and the slip in the right, the latter being supplied with clean oil. The back or convex side of the gouge must be laid level on the face of the oilstone, and the handle worked to and from the workman, who must roll it at the same time, so as to bring every part of the curve of the gouge in contact with the face of the oilstone. All the remarks upon grinding and oilstoning chisels apply with greater force to gouges, because the small amount of the surface of the gouge, in contact with either the grindstone or oilstone, renders it extremely liable to the formation of a feather edge in grinding, and a wire edge in oilstoning. In grinding outside gouges, a new feature steps in; for if the gouge be kept at the same inclination throughout the grinding, as in the case of all the tools heretofore mentioned, the center of the gouge will be keener than the corners; to avoid which the gouge is given a rolling motion to bring every part against the action of the grindstone, while at the same time lowering the back hand as the corners of the gouge approach the stone. This if evenly performed, gives an equal keenness to all parts of the cutting edge. The same rising and falling motion of the back hand is necessary in oilstoning the convex side of the gouge. The concave side is to be rubbed with an oilstone slip, taking care to let the slip be flat in the trough of the gouge and not elevated at the near end; for if once a habit of beveling, however slightly, the flat faces of tools is contracted, it tends to increase, so that the tools finally lose their characteristics, and are in fact ruined, so far as their application to good work is concerned.

Several sizes of squares are necessary to the pattern maker, because his work necessitates in many cases that the blade be short, in order to admit of its application to the work. Fig. 22 represents an ordinary try square; the blade should be of sawblade, and the back of hard wood, the inside and outside edges of the back being covered with sheet metal, to prevent undue wear.

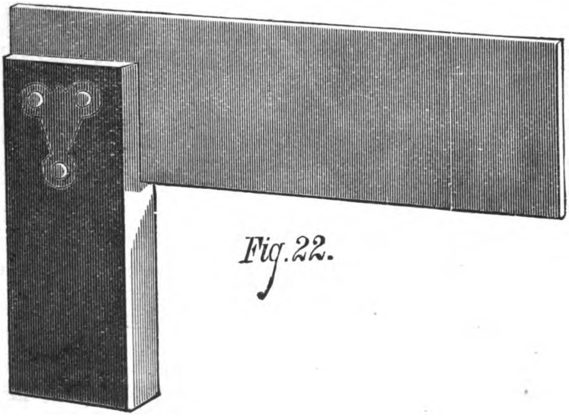


Fig. 22.

In Fig. F is shown a try square which can be used as a simple square or as a mitre square. By simply changing the position of the handle, and bringing the mitred face at the top of the handle against one edge of the work in hand, a perfect mitre, or angle of forty-five degrees, can be struck from either edge of the blade.

Fig. F.

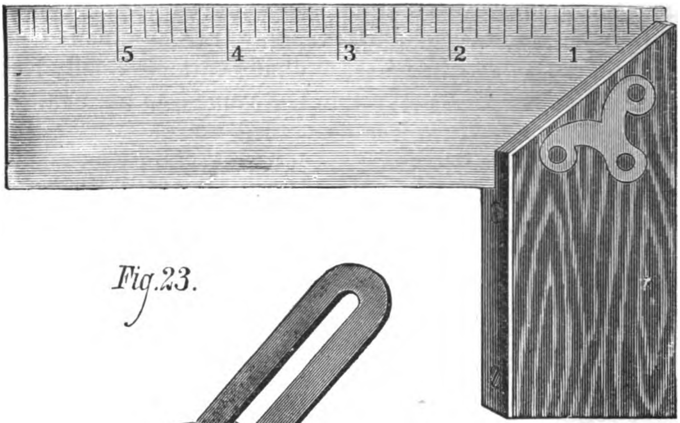
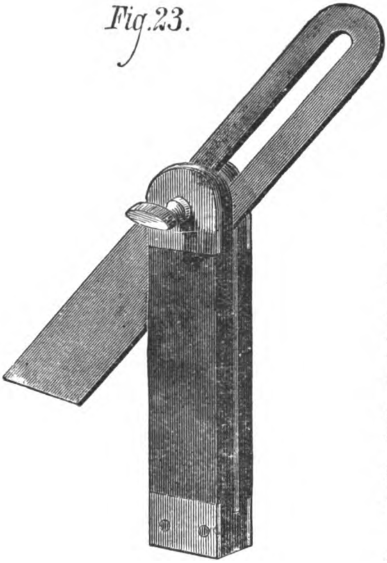


Fig. 23.



In addition to this, however, a bevel square is required; and it is best to have one with a sliding blade, so that the length it projects from the square back, on either side, may be adjusted to suit the work. Such a bevel square is illustrated in Fig. 23.

Of compasses there are two kinds, one being plain, and having no means of permanent adjustment, as shown in Fig. 24. This is used for casual measurements or marking. The other has an attachment by which it may be permanently set, as shown in Fig. 25, in which A represents a thumb screw employed to set one leg firmly against the radius piece, C, and B being an adjusting screw for finally adjusting the compass points after the thumb screw, A, is fastened, the spring, D, operating to keep the leg, E, firmly against the face of the screw, B; so that, when the adjustment of the compass points is once properly made, the compasses may be laid upon the bench and used from time to time without danger of the adjustment being altered by handling or by a slight blow.

Fig. 24.

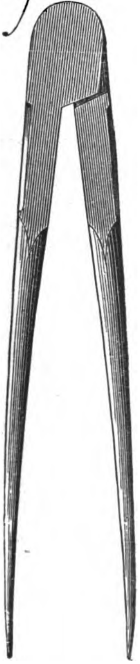
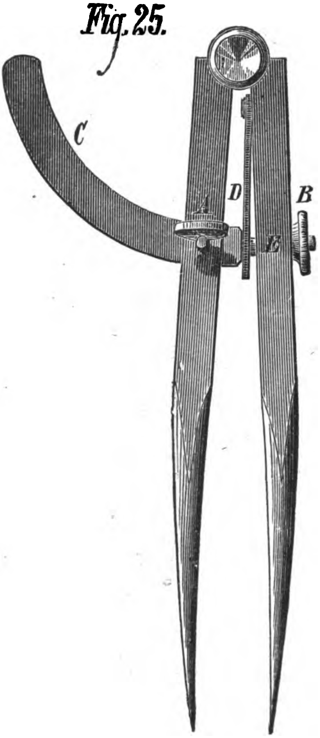


Fig. 25.



An excellent attachment for compass points has lately come into use; it is for the purpose of fastening to the marking leg a pencil, to avoid scratching the surface of the work with the compass point. This device and its mode of application are shown in Fig. 26, in which A represents a thin tube with the feet, G G, on it, and provided with the split, B. C is a clamp, provided with a thumbscrew, E.

Fig. 26.

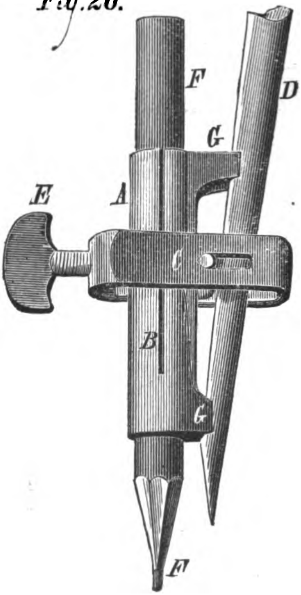
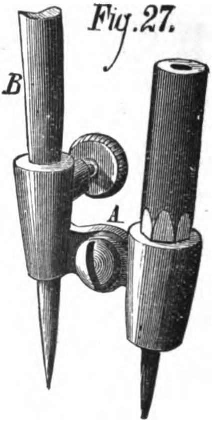
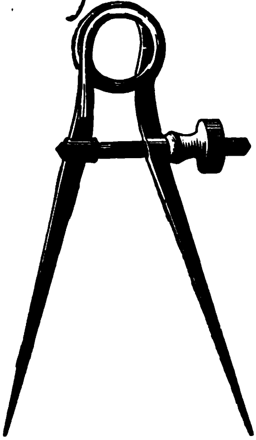


Fig. 27.



D represents one of the compass legs. F is a piece of lead pencil which passes through the tube, A. The attachment is slipped on the compass leg, and the screw is tightened up, clamping that leg to the feet, G G, and clamping at the same time the pencil in the tube. Another of these attachments, in which the pencil point is adjustable in a direction other than that in which the compass point stands, is shown in Fig. 27, the pencil tube being swiveled at A, and B representing the compass leg.

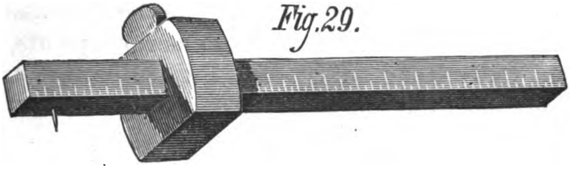
Fig. 28.



The points of compasses should be forged out when they get thick from wearing short, and they should be tempered to a blue color. For marking small holes, compasses are too cumbersome for fine work, and spring dividers are preferable. A recent improvement in these tools consists in making the spring helical, as shown in Fig. 20, instead of making it broad, flat, and thin, as formerly.

Of gages for drawing marking lines at any regulated distance from the finished edge or edges of the work, there are several kinds. First we have that shown in Fig. 29, which is the kind ordinarily sold; others have, instead of the set screw, a wedge running lengthwise, as shown in Fig. 30. A better gage, however, than either of these is that shown in Fig. 31, in which A represents the tightening wedge, standing at a right angle to the rod of the gage. The advantage of this design is that it requires only one hand to work it, inasmuch as the wedge may be loosened or tightened by striking it, as if it were a hammer, against

Fig. 29.



anything that may happen to lie on the bench. Thus the gage may be set and adjusted with one hand, while the other is holding the work, as is often necessary when marking small work. The marking point should be a piece of steel wire fitted tightly in the stem, the protruding part being ground or filed to a wedge, with the two facets slightly rounding, and whose broad faces stand at a right angle to the stem of the gage; the point or edge only projecting sufficiently to produce a line clear enough to work by; otherwise it will not be suitable for accurate work. The mortise gage is similar to the above as regards the stem and sliding piece, but it is provided with two marking points, their distance apart being adjustable. Fig. 32 represents the gage referred to, the head screw working in brass nuts. On account of the narrowness of the base afforded by the sliding piece on the common gage, there is not sufficient

Fig. 30.

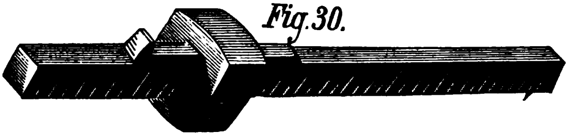


Fig. 31.

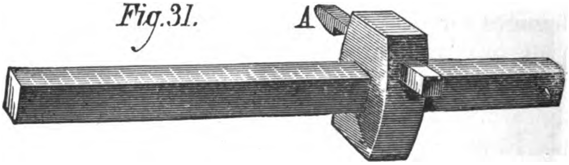
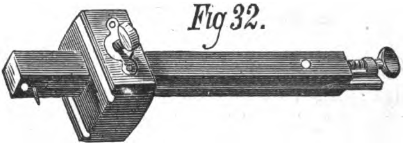


Fig 32.



steadiness to gage to any great width, so that for widths above ten or eleven inches we must have recourse to the gage shown in Fig. 33. It is called the panel gage; its sliding piece may be seven inches long, and the stem two feet; the rabbeting at A forms a steadying base, the part of the rod about the marking point being raised to correspond with the distance from the rabbet to the stem nut. Next we have the cutting gage, shown in Fig. 34, in which a steel cutter takes the place of the marking point, being wedged in position. It is employed to cut thin strips of wood; that is to say, of thicknesses up to about a quarter of an inch. The cutter point should be tempered to a dark straw color.

Fig 33.

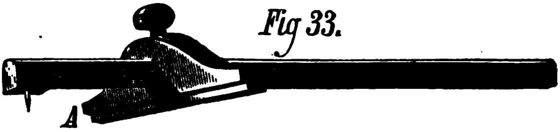
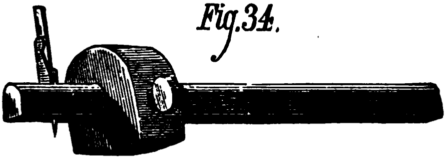
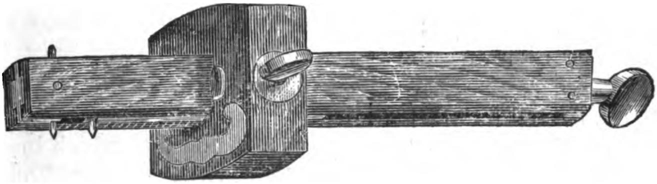


Fig. 34.



In Fig. G is shown a gage in which one side has a fixed point, and the other an adjustable one for mortise and other similar work, the movable point being operated by the thumbscrew shown at the end.

Fig. G.



For marking off curves or large circles, we require a pair of beam compasses or trammels, as shown in Fig. 35. They are composed of two sliding sockets, made of either wood or metal, fitted, at a sliding fit, to a staff. They are made of various designs, to suit the taste of the maker, and are often made by the pattern maker himself during his term of probation. The style shown in Fig. 35 is one very easily made. A A represents a staff of any desired length, composed of common pine. B and C are the two sliding sockets or holders; the mortises in them are made to fit the thickness of the staff, but they are longer than they are wide, to admit of the fastening wedge. They may be made of some hard wood, such as maple. The lower parts being turned and fitted with brass ferrules, a small hole is then drilled up the turned end of each, into which bradawls of large size are driven; they are then pointed on a grindstone. The wedges are made with a gib head on the small end, so as to prevent them from flying out when tapped back to loosen the sliding sockets from the staff, for

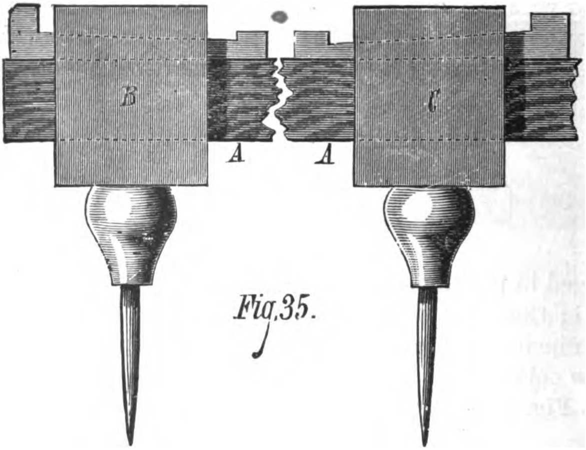
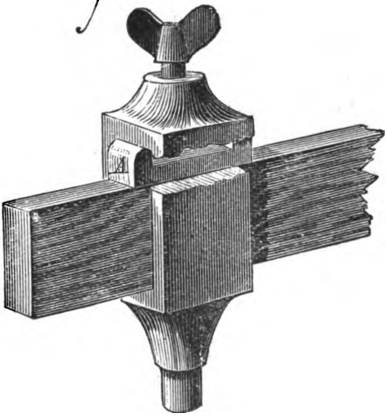


Fig. 35.

adjustment. If maple be used for the sockets, then the wedges may be made of a dark colored wood, sandpapered and varnished two or three times, which will give them a neat appearance. Made as above described, the trammels will be light and almost everlasting; and as the materials are always at hand, the cost is a minimum.

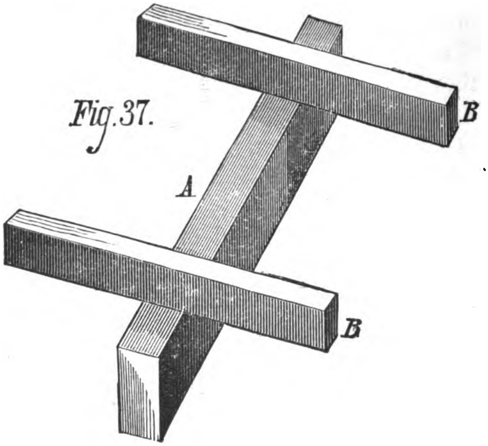
Fig. 36.



In place of the wedge, a screw may be, and sometimes is used, in which case a packing piece of either wood or sheet brass should be inserted, as shown in Fig. 36, at A, which will protect the staff from being indented by the end of the screw when the latter is tightened up.

Our next requirement is the straight edge, which, for small work, is better of steel than of wood. A straight edge is a piece of stuff whose edges are straight and parallel to each other, which is necessary because they are sometimes used in conjunction with the square. A pair of straight edges, termed winding strips, are indispensable; their use is shown in Fig. 37, in which A is a piece of work requiring to have its edge true; B B are the winding strips, placed on the work as shown, so that by casting the eye along the upper edge of one strip, and leveling the head so that the edge of one strip will be brought nearly horizontally level with the other, it will readily be perceived whether the two are level one with the other, and hence whether the face of the work is true. Winding strips are simply pieces, of wood made parallel and true, and generally about two feet long, three or four inches wide, and about five-eighths of an inch thick. When the edges have been made as straight as possible with the truing plane, one of these should be lightly chalked on its edge face and laid upon the other, and then moved back and forth through a distance of about one-half inch. The upper one should not be pressed to the lower, but allowed to lie of its own weight; otherwise it will spring to suit the outline of the lower one, or bear upon it at the points pressed by the hands. Before separating the two, take a blacklead pencil and make a mark on one side of each, so as always to be able to bring the pieces together in the same way. Then separate them and ease away the high places, continuing the truing operation until they bear all over. In placing them upon the work, be careful that they stand parallel to each other; that is to say, that the distance between them is about the same at each end, otherwise the eye will be misled in sighting them when on the work.

Fig. 37.



In Fig. 38, we have an ordinary screwdriver, the point of which should be shaped as shown at A, in Fig. 39, and not as shown at B, as is usually the case, because if the part entering the screw head is tapered, it not only raises a burr on the screw head, but it is liable to slip out, even from a screw that drives easily, and much more from one that drives hard. To grind it to the shape shown at A, it should be ground on that side of the stone in which the latter is running toward you, the length of the screwdriver being at a right angle to the plane of the stone and the handle held in one hand, while the driving end is held in the other, which should be supported by the grindstone rest. If the stone is a small one, the screwdriver, while being ground in this position, should be moved a little, so that first one corner and then the other will approach the stone, so as to prevent the grinding from being hollow, which would weaken the screwdriver point by thinning it in the middle. Screwdrivers should be made of cast steel, and tempered at the point to a blue color.

Fig.38.

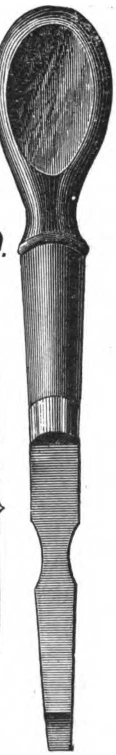
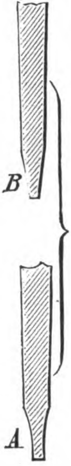


Fig.39.



The mallets should be of hickory, and of the form shown in Fig. 40; the sizes being, one 2½x3x5 inches long, and another about 3x3½x5½ inches long, the handles being mortised and properly wedged to the head.

Of oilstones there should properly be two, one for roughing and one for finishing. Wichita or Arkansas stones are even in grain and cut well, and are the best for our purpose. In addition to the large oilstone, a number of slips of oilstone are necessary, some being flat, others half round and flat, with round edges, their uses being for gouges and other tools in which the cutting edges are hollow or curved. The general oilstone should be kept with a flat face, otherwise it will be impossible to properly set plane blades, firmer and paring chisels, and other similar tools upon it. With this object in view, the workman should set small tools upon the ends, so as to prevent the stone from becoming hollow in the middle. When it becomes necessary to grind the face of the oilstone, it may be done upon the grindstone; but a better plan is to take a flat board and liberally supply it with clean sand and water, and then grind the oilstone on it by hand, leaving the face a little rounding in its length, by easing it off at each end, but leaving it flat across the face, by which means it will last longer without regrinding. There are some stones which are used with water instead of oil; they do not cut, as a rule, very freely, but the finer grades of them will cut unusually smooth. These are the descriptions used by the Japanese workmen, who use two stones, one to rough cut, which cuts very freely; the other to finish, which seems to grip the metal firmly, rendering it easy to keep the tool at the necessary angle and level, while at the same time it cuts very finely indeed. The first is a bright yellow stone, the latter is of a green slate color—hot water being used on both of them. Aside from those already mentioned, we have the Turkey stone, a close-grained and amber-colored stone, which cuts

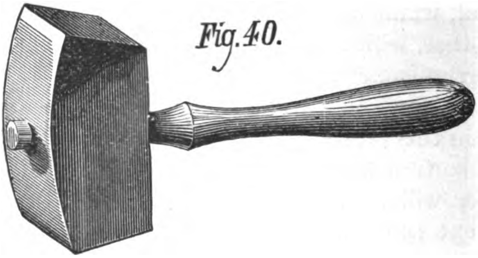


Fig. 40.

freely or fine, according to the grade of the stone. For all ordinary purposes the Arkansas stone will suffice, and it is obtaianble at almost every hardware store. The oil-stone for general use should be fitted into a block of wood, having a margin outside of the stone of one half inch on each side, and about an inch at each end, the block being hollowed on the bottom face so that it will stand firmly and not rock when in use. It should also be provided with a cover, to prevent dust and dirt from accumulating upon it.

Two pairs of inside and three pairs of outside calipers are necessary to the pattern maker, the smallest of each pair being large enough to take in diameter up to four inches, the largest from four up to about ten inches. The other pair of outside calipers may be large enough to use upon diameters from ten to eighteen inches. For bores above ten inches a wire gage may be used, by bending a piece of wire as shown in Fig. 41, which may be shortened by being bent more, or lengthened by being straightened. It is preferable to make an adjustable gage, such as shown in Fig. 42, in which A and B represent two sliding pieces of steel, and C and D screws and nuts. It is obvious that, when the screws are loosened sufficiently to just let the sliding pieces move by a slight tap, the gage may be extended by striking the ends, E, or either of them, their in-

Fig. 41.

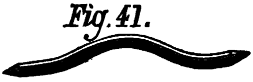
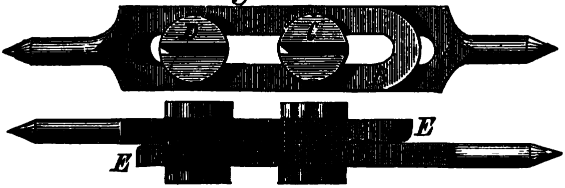


Fig. 42.



side edges being rounded off to prevent them from burring. It is better to set them at first a little below the required size, and to perform the adjustment by opening them, so as not to require to strike the point at all. The points should, however, in any event, be tempered to a blue. It is an excellent plan to file away the screw heads on two sides, a little, say $\frac{1}{32}$ inch, thus forming a sliding piece under each head to fit into the slot of the gage, which will prevent the screws from turning when screwed or unscrewed, and in the end save much annoyance. A small machinist's square and a steel rule are also necessary for small fine work, the wooden ones being too clumsy. The edges of the rule should be trued so that it may be used as a straight edge.

CHAPTER II.

LATHE — LATHE CHUCKS, AND LATHE TOOLS.

To give the required form to various patterns, recourse must frequently be had to that useful machine, the lathe. The lathe adapted for pattern work is strong and steady in the framework, to avoid the tremor resulting from the high speed at which it is driven. It should be of good and durable workmanship, and should also be handy; that is to say, the parts requiring frequent adjustment should be provided with the readiest means for accomplishing that end; and especially is this the case with the hand rest and the manner of holding it to the lathe bed, as it is, in the progress of a piece of work, almost constantly changed in position. Fig. 43 shows the method, still followed by many wood turners, of holding the hand rest; it is a prim-

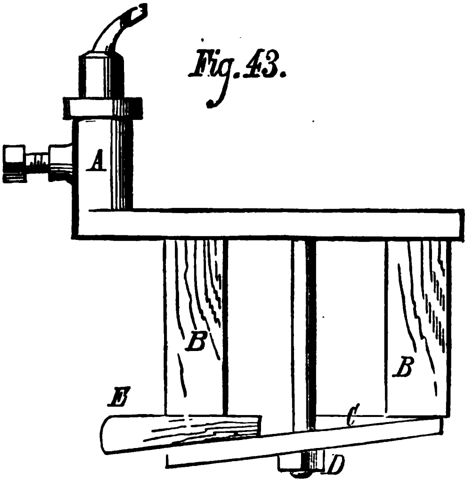
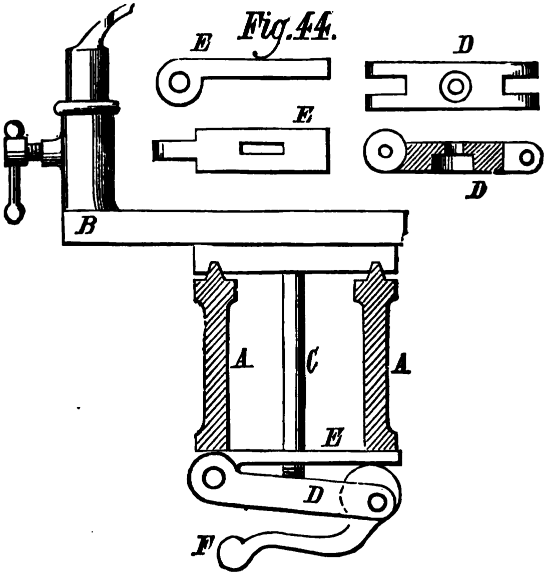


Fig. 43.

itive arrangement, but the tightening and loosening of the wedge, E, is found to take less time than screwing up the nut D. In Fig. 43, A is the hand rest, B B the lathe shears, C the clamp, and D the nut upon the bolt, E, the head of which slides in a groove running along the foot of the hand rest. It will be observed that the nut, being beneath the lathe shears, is somewhat unhandy to get at, and the wrench may not perhaps at the moment be at hand; while, in any event, screwing up a nut with a wrench is a slow process. In some cases there is substituted, for the nut, a wheel with a tapped hole in its center; but it is still not perfect, because the workman, in slacking it off, gives the wheel a twist; and while his attention is absorbed in the intricacy of his work, the momentum of the rim of the wheel has kept it turning, so that it either unscrews itself altogether and falls off, or runs so far back that it requires handling twice to bring it home when refastening it. A much better method is now in many cases adopted; it is shown in Fig. 44, in which A A represents the lathe shears, B the hand rest, C the fastening bolt, D a piece hinged at each end and having through its center a hole to receive the fastening bolt, and a countersink or recess to receive the nut and prevent it unscrewing. E represents a hinged plate, and F a lever having a cam at its pivoted end. A slot for the fastening bolt to pass through is provided in the plate, E. In this arrangement, a very moderate amount of force applied to bring up the cam lever will cause the plate, D, to be pressed down, carrying with it the nut. This arrangement is simple, cheap, durable, and very handy, and may be applied on any existing lathe to the hand rest, slide rest, or tail stock. There are other simple and useful contrivances devised for the same purpose; but generally speaking, the lathe requires to be designed to accommodate them, and they are not superior in action to the system above described.

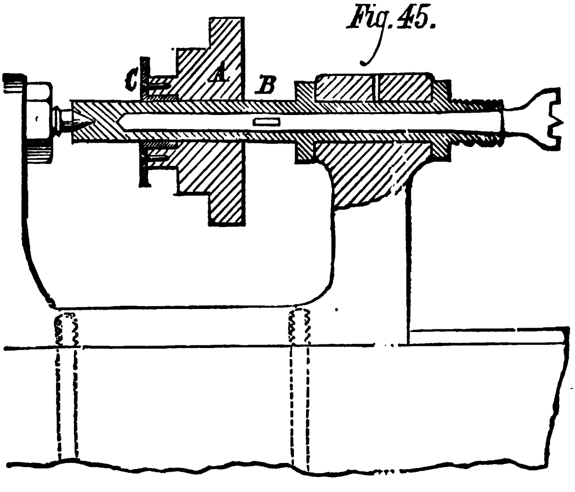
The running head of the lathe requires particular mention. The mandrel should always be of steel, turned true, hardened, and trued by an emery wheel, after the hardening process. It should be well fitted to its bearing; for if it is not, an unpleasant jarring noise will be produced when the latter is set in motion.

Fig. 44.



Hard steel coned bearings are very desirable, and will work perfectly when properly made, lasting practically unimpaired for years. They are, however, expensive to make; and in view of the present active competition in producing cheaply, most mechanics, knowing the difficulty attending the proper fitting of this style of mandrel, feel more or less dubious as to the perfection of such lathes until they have been well tried. Next to a hard steel coned bearing, we should prefer a cylindrical one of hard brass; that is to say, a mixture of five parts copper, one part tin, and one quarter part zinc. The length of the journal should be three times its diameter; the brasses should be made in halves, and adjusted so that the faces of the brasses are butted when the cap screws are tightened home, and the journal is at a neat working fit in the bearings. It will then be a long time before the brasses will require letting together for adjustment. If, however, the joint faces of the brasses are left open, the cap screws are apt to slack back, there being no pressure on them, to retain them in their places. It is an advantage to have the mandrel bored nearly through its length, say within one inch of the tail pin or screw, whose coned end forms the bearing for that end of the mandrel. The size of the hole referred to should be as large as consistent with the strength of the mandrel. This arrangement is shown in Fig. 45.

Fig. 45.

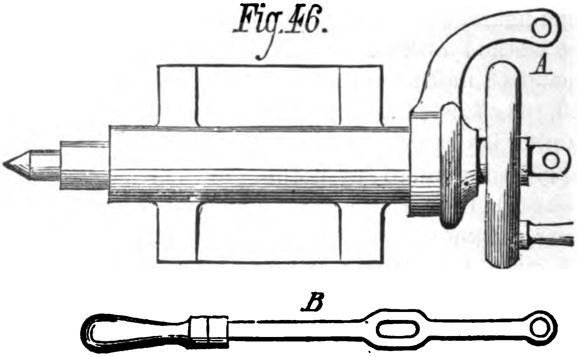


The usefulness of this bore or hole is that when a number of small pieces require to be turned, a nipping chuck can be screwed on the mandrel, and a long piece of stuff can be pushed up the hole, and the projecting end to be operated upon nipped in the chuck; then, when a piece is finished, all we have to do is to advance our long piece of stuff and proceed again.

The method ordinarily employed is to drive a plug into the mandrel, and form the projecting end to the shape required. By this plan more stuff is lost than is used; and if the plug is not well fitted and driven, it loosens while being operated upon, to say nothing of the trouble of extracting the stub from the mandrel when the work is cut off. Another purpose served by the long bore is that it will form a guide for a boring bar.

The cone pulleys should be as light as possible for a power lathe. Hard wood is very suitable for them, the manner of fastening to the mandrel being shown in Fig. 45. The cone pulley, A, is bored to fit the mandrel, B, tightly, and secured at the end to receive the light brass bush, C, which is keyed to the mandrel and screwed to the pulley. The reason for making the cone pulley of wood is that, if it were of iron, and consequently heavy, it would, from its weight, require time to get up to its full speed; and from its momentum, it would take some little time to stop in both cases, especially if the work were heavy. The tail stock should, in addition to the hand wheel be provided with an arm; and a lever, to give rapid motion to the spindle when used for boring purposes, should be added, the arrangement being as illustrated in Fig. 46, in which A represents the arm or fulcrum, and B the lever, which is applied after the hand wheel is removed. The end of the screw must be cut like a double eye. The long hole or slot in the middle of the line is to allow for the difference in the direction of the motion, since the lever moves from its end as a center, while the tail stock spindle moves in a straight line. The supporting frames of the lathe need not be very heavy, but should be well braced to the shears or bed, and screwed fast to the floor. It is not an uncommon thing, when an unusually large job is being done in the lathe, to brace or shore the lathe by means of braces placed between the lathe shears and the floor, wall, and ceiling. Of this arrangement it is sufficient to say that it is merely a make-shift, and is only resorted to when the floor is springy. In cases where it is necessary to use one lathe for both large and small work, the countershaft overhead should be so placed that the belt will run quarter-cross when the lathe head is placed across the bed, in which position there will be full swing for large work from floor to ceiling.

Fig. 46.



It remains now to provide, for large work, a means of supporting the hand rest. The handiest is the portable tripod rest shown in Fig. 47. The legs, A A A, are curved so as to get the rest close up to a large chuck. Heavy weights, in the form of a U, as shown at B B B, may be clamped, by means of the set screw, to the legs, to give additional steadiness if required; but if good spread be given to the legs, so that they may form an angle of about 60° to the floor (taken from the point of the foot to where the leg joins the hub), the weights may be dispensed with; and at the same time more space will be occupied, so that it may not be possible at all times, on account of surrounding objects, to get such a broadly spread rest into the position required; hence a narrower spread in conjunction with the weights, is, under such condition, the most desirable.

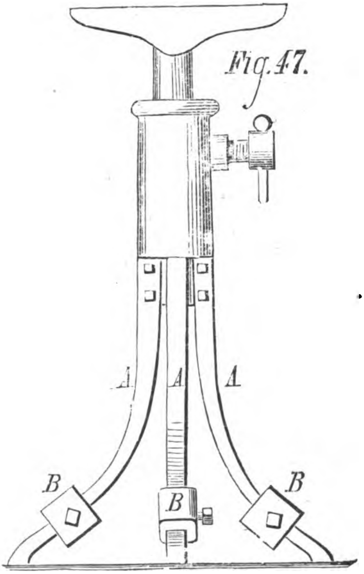


Fig. 47.

We come now to the various chucking contrivances employed by the pattern maker. In Fig. 48, A represents a fork center, the taper part of which fits into the lathe mandrel in place of a center, the extreme end, B, being a flat projection, providing that there is a recess in the mandrel to receive it, as there should be. But if the lathe mandrel is bored up a great distance, then the extra length which may be given to the conical part of the fork will cause adhesion sufficient to drive the work. The broad part is wedge-shaped on the edge view, the center point, C, being turned conical, similar to a common center. The center, C, acts to keep the work true, and as a guide in taking the work in and out of the lathe, while the prongs, D and E, drive it. This tool,

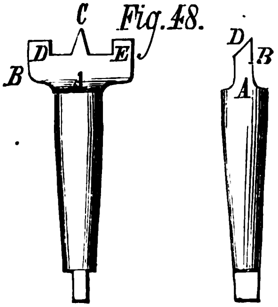


Fig. 48.

however, is only to be depended upon for small work; for larger work, center plates are used. They are made of metal and screwed firmly to the work. Of these center plates, one has a slot in it, so that it may be used in conjunction with the fork; while another has a conical hole in the center, which hole is made to fit the back center of the lathe. They may be made of hard wood, screwed to a small iron face plate; such plates are made useful for a variety of purposes. A pair of such center plates are shown in Fig. 49—A being that to receive the back center, and B that for the fork center. Another driving chuck for small work is shown in Fig. 50, the part, A, having an internal screw to fit the driving screw on the lathe spindle, and the point, B, being a coarse screw intended to screw into the work; which latter should have a small hole bored up it to prevent (especially in the case of hard woods) the pressure of the screw from splitting the work.

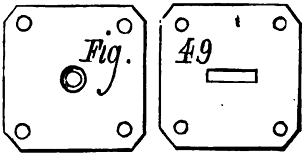


Fig. 49

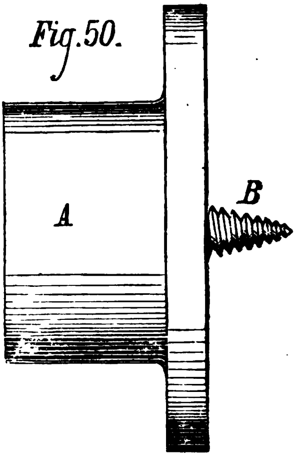


Fig. 50.

From the appliances for turning work between the centers, we pass to those for holding work independent of the back center of the lathe by means of chucks, the name by which such appliances are generally known. Fig. 51 is a back view of a face plate, to which work may be held by screws; the usual method, however, is to screw to the face plate a disk of wood, and then to true the wood across the face and on the diameter. The work is then fixed to the new surface thus obtained. Many good purposes are served by the intervention of the disk of wood (or chuck, as it is usually termed) between the metal plate and the work. For instance, it is a guard which effectually prevents the turning tools from touching the metal of the face plate. It supports the work (being nearly of the same size) when required, and obviates the necessity of having more than three or four face plates of metal. Its surface is readily made to conform to the shape of the work, and furthermore it is very readily trued up. When we have to deal with large sizes, a mere disk of wood will not serve, as it will be too weak across the grain: and here it may be remarked that the work often supports the chuck, and therefore we should always, in fixing, make the grain of the work cross that of the chuck, because the centrifugal force due to the high velocity is so great that both the chuck and the work have before now been rent asunder by reason of the non-observance of this apparently small matter. When it is considered that the chuck has not sufficient strength across the grain, battens should be screwed on at the back; but a chuck so strengthened will require truing frequently, on account of the strains to which its fibers will be subjected from the unequal expan-

Fig. 51.

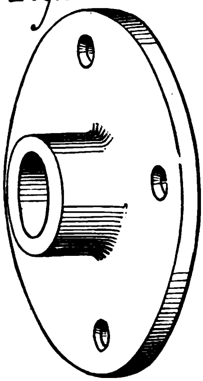
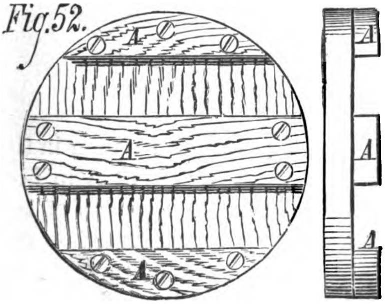


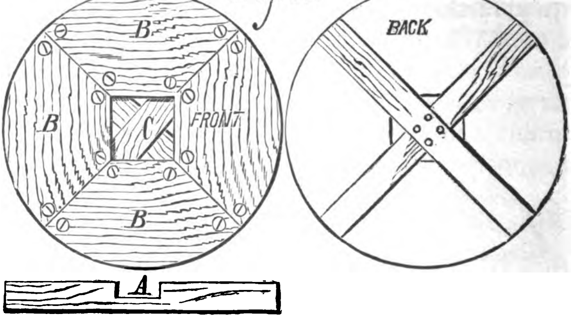
Fig. 52.



sion or contraction of its component parts. Fig. 52 shows the back of a chuck strengthened by the battens, A A A.

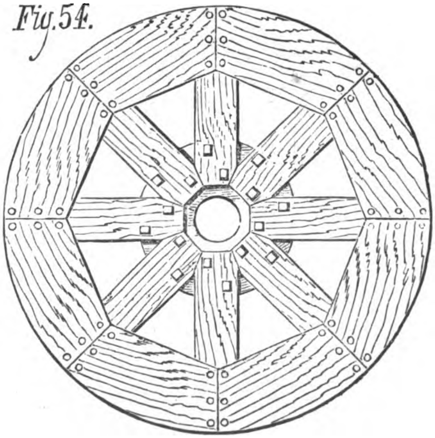
Another method of making a chuck is shown in Fig. 53. It is considered superior to the former, from its greater ability to resist outward strains in every direction, while the strains to which it must necessarily be subject, from variations of temperature and humidity, are less than in the former. It will also be found that it can be trued with greater facility, especially on the diameter, as the turning tool will not be exposed to the end grain of the wood. To make one of these chucks about 2 feet in diameter, we proceed as follows: Procuring two bars for the back, say 4x2 inches and 2 feet long, we plane them all over; then in the middle of each we cut out the recess (shown at A in Fig. 53) to a depth equal to half the thickness, the width of the recess being equal to that of the bar; this process is termed half checking. We next fasten these bars together by gluing and screwing them at the center, driving the screws thightly home while the glue is warm. Upon the cross thus formed, we superpose the segments shown in the front view of Fig. 53, at B B B; these may be of almost any thickness, say from ⅞ to 1½ inch. They should be planed on the back, and should not extend to the center, but leave

Fig. 53.



an open space (as shown in Fig. 53, at C) of about 4 or 5 inches. This opening can be filled, if desired, by screwing on a square piece. If the segments were carried to the center, they would be too weak to bear a screw near that point; and again, in large chucks we very seldom require to use the part about the center. Chucks of very large size — that is to say, from 4 feet upwards — will require more support than is afforded by the four arms of the cross. Three bars can be put together, so as to give six arms, which will answer probably for a 6 or 7 feet chuck. For still larger sizes, it is necessary to cast a strong circular plate to form the middle of the chuck, and to then bolt the requisite number of arms to it. The strength of the chuck will of course depend upon the number of arms and their depths; and unless the chuck is very substantial, a difficulty will be experienced in turning, on account of the tremor. A chuck having the middle of iron and the outside of wood, supported by arms, is shown in Fig. 54.

Fig. 54.



In shops where the size of the work necessitates the employment of chucks of so large a diameter, a special lathe is of great advantage, because a lathe having an elevated bed is so tremulous and shaky; while those having large solid heads are too cumbersome, and are not belted to run at a sufficiently high rate of speed. In such cases, the arrangement shown in Fig. 55 is an excellent one. A represents a lathe head bolted firmly to two uprights, B B, which are firmly fixed to the joists, C, and to the flooring at D, right over and upon the joists supporting the flooring, or else

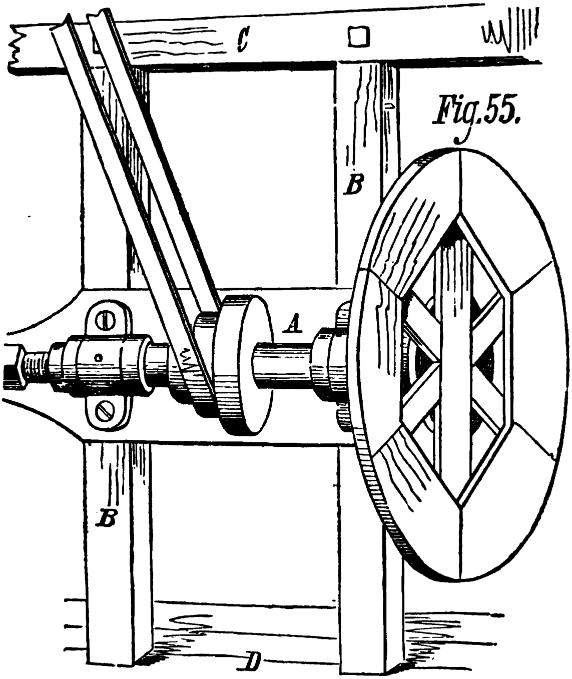
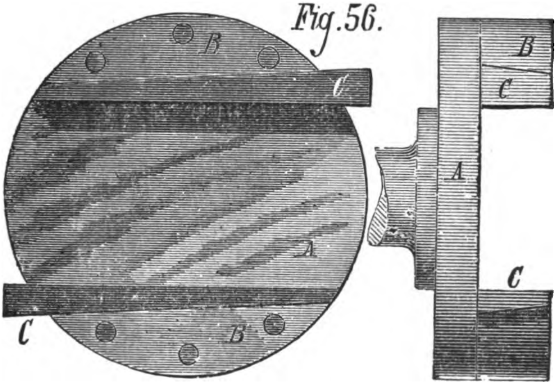


Fig. 55.

upon beams provided for the purpose. By this means the work may, if the lathe head is fixed midway upon the posts, B B, be as large as the space between the ceiling and the flooring will admit, a movable tripod rest, such as shown in Fig. 47, being employed for a tool rest.

Fig. 56 represents a side and face view of a very useful chuck, suitable for holding core boxes while boring them. It is shown attached to one of the metal plates that fit the mandrel of the lathe, and is usually made of hard wood; but for a large sized one, say 15 or more inches in diameter, the disk portion, A, may be made of pine wood. The

Fig. 56.



two sides, B B, are firmly fixed to the disk, their inner edges being planed at an acute angle to it. The work is held by driving the wedges, C C, and may be truly chucked by them in a comparatively short space of time.

Another very useful chuck is shown in Fig. 57. It will answer the same purposes as that shown in Fig. 56. It is, however, made entirely of metal, somewhat similar to a machinist's dog chuck, but much lighter. Pieces of wood may be screwed on the jaws at A A, and bored to the curvature of any round piece of wood—an advantage which the chuck shown in Fig. 56 does not possess. Or the jaws may be turned round in their places, so that the faces, A A, will stand outwards, and the wooden pieces screwed thereon may be made to fit a hole. This chuck will be found to save much time over the plan of screwing work to the common face plate. V pieces of wood may be fixed to the jaws, and a piece of work in the rough held by them during the process of facing, boring, and turning the projecting part. The work can then be reversed in the chuck, and similar operations performed on the opposite end; and the work can be taken from the lathe and tried as to either

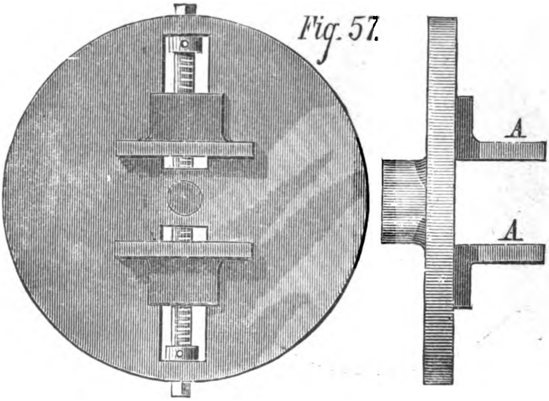
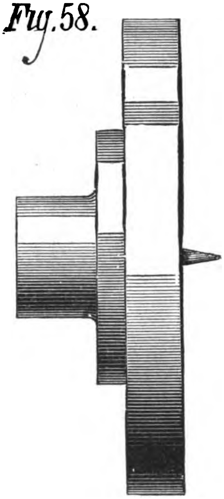


Fig. 57.

fit or conformation, and, if necessary, restored in a moment to its original position in the chuck, so as to run quite true; but at the same time, for first class work, it is better not to use the V's on finished surfaces. For holding bits and small work, neat little chucks may be purchased at the hardware stores, and they act similarly to the nipping arrangements applied to boring braces. These chucks can be supplied to screw on the lathe mandrel; or they will, with a taper shank, fit into the taper holes provided to fit the lathe centers. It is well to have one of each, so as to be able to use one of them in place of the still lathe center, to operate upon work already chucked on the face plate of the lathe.

A simple and very useful chuck still remains to be described, being what is known as the cement chuck, which is made as follows: A disk of hard wood is screwed to a metal plate, where it should remain permanently; but if the face plate cannot be spared, bore a slightly taper hole through the disk, a little smaller than the diameter of the screw of the lathe mandrel, and partly through the disk. Then screw the disk on the mandrel, working the disk backwards and forwards to form a thread in the bore of the disk, and then turn and face it perfectly true. Then bore a small hole in its center, and drive in a piece of soft steel wire, leaving a short length projecting from the face, and turn it to a point, as shown in Fig. 58.

Fig. 58.



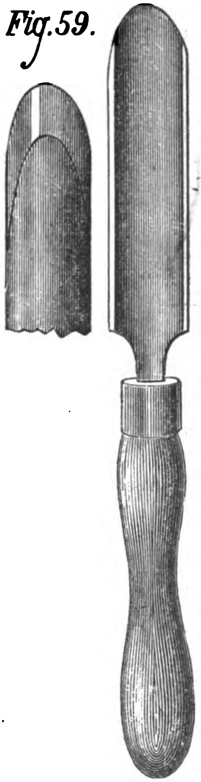
The object of this chuck is to drive thin, delicate work, which it would be difficult to screw or clamp by adhesion, and this is accomplished as follows: We first prepare a wax, composed of 8 parts of resin to 1 of the best beeswax, melted and well stirred together, and run into tubes of paper or other suitable molds. To chuck the work, we take a stick of the wax, and press its end against the face of the chuck while the lathe is running, and then place the center of the piece of work on the steel point, applying sufficient pressure to cause the steel point to force its way into the work. Just before the work touches the wax surface, we throw the lathe belt on to the loose pulley; and the momentum of the lathe, combined with a moderately heavy pressure, will generate, by friction, sufficient heat to melt the wax and cause the work to adhere to the chuck. The work may be detached, when necessary, by inserting behind it a thin wedge or blade.

TURNING TOOLS.

The turning work necessary in making patterns is usually done by hand; although on small and plain work.

such as simple boring and facing, slide rest tools may be used to advantage, inasmuch as they will operate quicker than hand tools. Since, however, pattern lathes are not usually provided with slide rests, we shall confine our remarks to hand tools. For roughing out, the turning gouge, shown in Fig. 59, is used. In grinding this gouge, it is necessary to lower the back hand when grinding at and towards the outside corners, so that the cutting edges may be formed, by the junction of two faces, at as acute an angle as those forming the cutting edge in the centre of the width of the tool.

Fig. 59.



It is always the custom to reduce the work in the lathe to nearly the required form by this tool, the finishing tools being (with one exception) simply scraping tools, and not, properly speaking, cutting tools; hence it is evidently inadvisable to leave much for them to take off. The manner of holding the gouge is shown in Fig. 60. One hand grasps the handle near the end, while the other grasps the gouge near the cutting point, that is to say, as near as the hand rest will permit. It is sometimes, however, necessary to slightly vary the manner of holding, by passing the forefinger of one hand around the hand rest while the gouge is confined between the thumb and forefinger, thus gripping the gouge end to the rest. This is advisable when turning a piece of work that is not completely round, as, for instance, tipping off the teeth of a gear wheel, in which case gripping the gouge to the hand rest will steady it and prevent it from digging into the work. The gouge is shown, in Fig. 60, to be cutting from right to left; it will, however, cut equally well if used from left to right, in which case the position of the hands must be reversed, the left hand gripping the gouge near the cutting edge. In either case, however, the gouge is not held horizontally level, but is tilted to one side, the lower side being the cutting one, otherwise the tool would rip into the work.

Fig. 60.

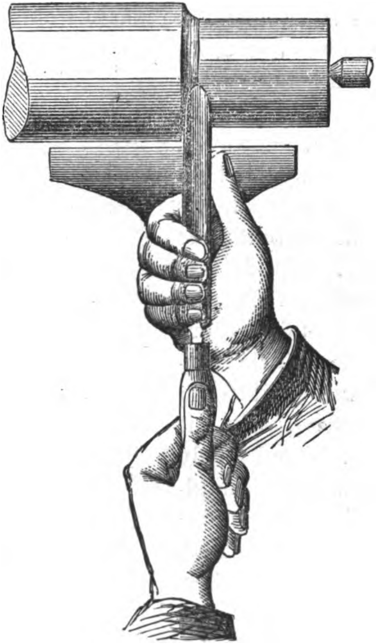
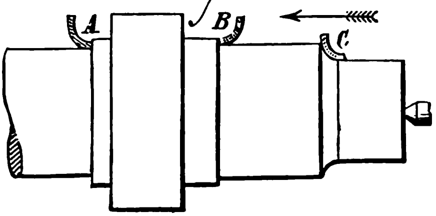


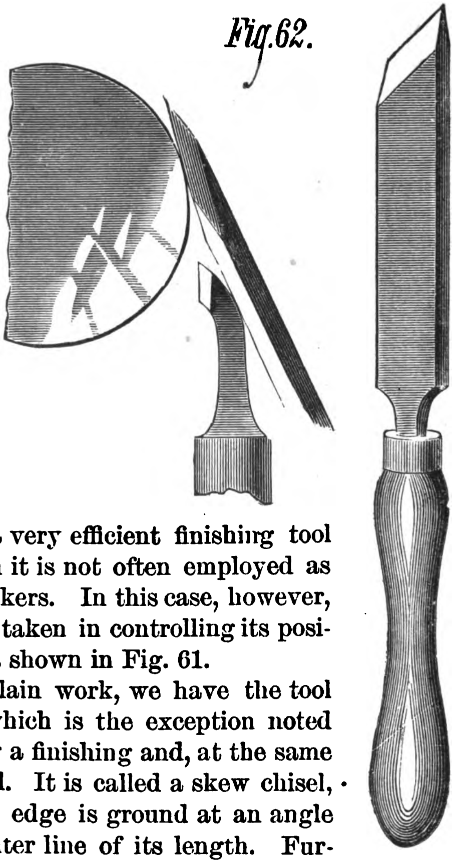
Fig. 61 shows the section of the tool and the tilt of the tool when cutting from right to left; while that of the tool, A, shows tilt when cutting from left to right. The reasons for this are as follows: The face of the gouge, on its hollow side and near the cutting edge, receives the strain which is necessary to curl the shaving, that is to say, which is necessary to force it out of the straight

Fig. 61.



line. But if we were to place the gouge in the position shown in Fig. 61, at C, the whole of this strain would be placed upon the gouge, tending to force it forward and into the cut, as denoted by the direction of the arrow; and as a consequence, the gouge would run forward and dig into the work, in spite of all endeavors to prevent it. When, however, the gouge is held in the positions relative to its line of travel to its cut, shown in Fig. 61, at A and B, there is but little tendency for it to run forward, and it can be fed easily to its cut. In addition to its use as a roughing tool, the gouge makes a very efficient finishing tool for hollows, though it is not often employed as such by pattern makers. In this case, however, great care must be taken in controlling its position to the work, as shown in Fig. 61.

Fig. 62.



For finishing plain work, we have the tool shown in Fig. 62, which is the exception noted previously as being a finishing and, at the same time, a cutting tool. It is called a skew chisel, because its cutting edge is ground at an angle or askew to the center line of its length. Furthermore, it is beveled at the cutting end on both sides (as shown in the edge view), being ground very keen. It is employed for finishing straight or parallel surfaces, and for dressing down the ends or down the sides of a collar or shoulder. When used for finishing straight or parallel surfaces, it performs its cutting in the center of the length of its cutting edge only, as shown at A, in Fig. 63, and is held in the position relative to the work shown in Fig. 62. When nicely sharpened it leaves a polish, unlike other finishing tools; but with these advantages, it has a drawback (and a serious one) to learners, as it seems to have a terrible propensity for tearing into the work, whether it is used upon the circumference or facing the shoulders of the work. This difficulty can only be overcome by practice, and the reason lies in the difficulty of learning how to handle the tool with dexterity. It must be held almost flat to the work; and yet, if it should get quite flat against the work, the cutting edge would cut along its whole length, and the pressure of the cut would be sufficient to force the tool edge deeper into the work than is intended, which process would continue, causing the tool to rip in and spoil the work. The face of the chisel nearest to the face of the work being operated upon, stands almost parallel, with

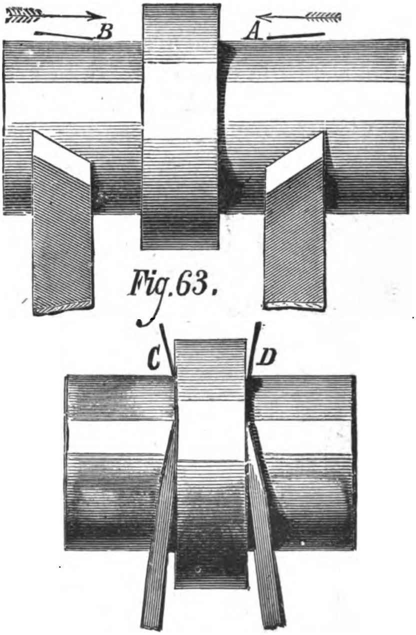


Fig. 63.

just sufficient tilt of the tool to let the cutting edge meet the work in advance of the inside face of the tool; or in other words, the amount of the tilt should be about that of the intended depth of the cut; so that, when the cutting edge of the tool has entered the wood to the requisite depth, the flat face will bear against the work and form a guide to the cutting edge. The corner of the chisel which is not cutting must be kept clear of the work. Fig. 63 will convey the idea, the arrows showing the direction in which the chisel is, in each case, supposed to be traveling.

The short lines, A and B, under the arrows, and those touching the collar, at C and D, show the tilt or incline of the chisel to the work. In turning the circumference, the obtuse corner of the chisel is the cutting one; while in turning down a side face, it is the acute angle. Most pattern makers, however, do not often use the skew chisel for finishing straight cylindrical work, because it is liable to make the surface of the work more or less wavy. It is, however, almost always used for cutting off and for cutting down shoulders, for which purpose it is highly advantageous. For circumferential work on cylindrical sur-

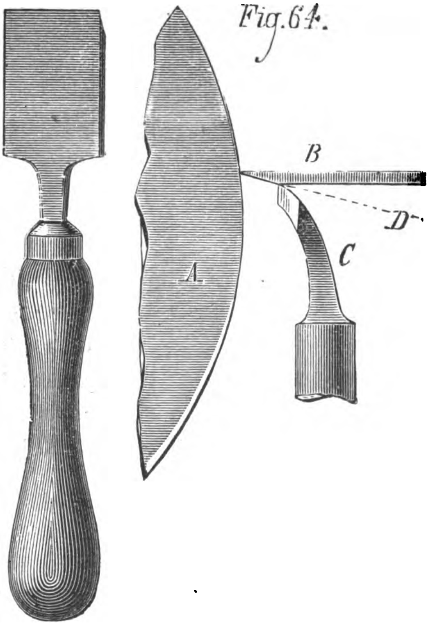
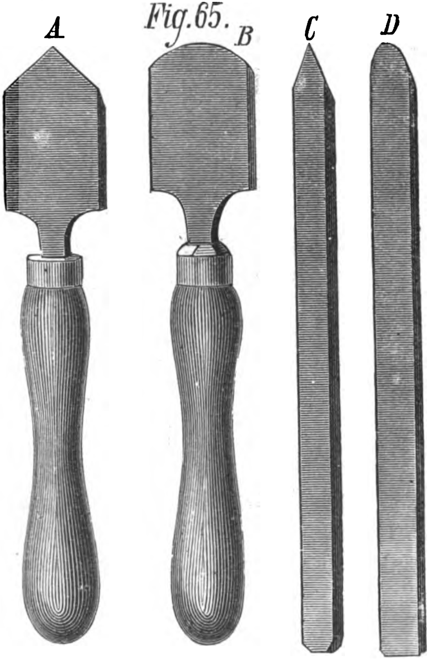


Fig. 64.

faces, an ordinary chisel is mostly employed, the position in which it is held to the work causing it to scrape rather than cut. A worn-out paring chisel is as good as any. Such a chisel is shown in Fig. 64, the position in which it is held being illustrated by A, which represents a section of a piece of cylindrical work; B representing the chisel, and C the hand rest. Some pattern makers prefer to increase the keenness of this tool by holding it so that the plane of its length lies in the direction denoted by the dotted line, D; this, however, renders it more likely to rip into the work, and the position shown is all that is necessary, providing the cutting edge be kept properly sharpened. This chisel is also used on side faces.

Fig. 65.



Still another tool, sometimes used for finishing plain cylindrical surfaces and side faces, is that shown in Fig. 65, at A. It is used in the same manner and relative position as the chisel shown above, in Fig. 64.

For finishing hollows, which should first be roughed out with the gouge, the form of tool shown at B, in Fig. 65, should be used. Several of these tools, of various sizes, should be kept; they are used in the same position as the finishing chisel, shown in Fig. 64. The tool shown at C, in Fig. 65, is used upon large work, and is advantageous because it presents less surface of cutting edge in proportion to the depth of the cut than the gouge; and, in consequence, it is less liable to cause the work to jar or tremble. It is usually made about 2 feet long, which enables the operator to hold it very firmly and steadily. It is used with its top face lying horizontally, and should be kept keen. D, in the same figure, represents a similar tool, with a round nose; this latter is not, however, made long, and may be used in a handle.

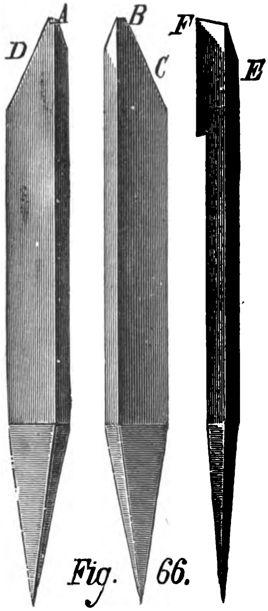


Fig. 66.

For boring and shouldering purposes, the tools shown in Fig. 66 are employed; those shown at A and B, having their cutting edges at C and D, are therefore right and left hand tools. When, however, the hole is too small to admit of those tools being used, that shown at E may be employed, its cutting edge being at F.

The temper of all these tools should be drawn to a light brown color, and the instruction given for grinding bench tools should be rigidly observed in grinding and oilstoning these turning tools.

CHAPTER III.

THE FOUNDRY.

HOW A PATTERN IS MOLDED.

IT has been already remarked that the operations of the molder are, to a large extent, predetermined by the pattern maker; hence it becomes necessary that the latter shall have a knowledge of foundry work, otherwise he is likely to make the patterns very expensive and awkward to mold. In learning the trade, an apprentice is usually put to work and distinctly instructed as to the required form of his work, without knowing anything of the reasons therefor. In this way he attains a practical knowledge of how different classes of patterns should be, or are, usually made; but it takes him years to become an expert mechanic, for the reason that, having learned by rote, he is incapable of meeting new conditions to the best advantage, until his experience has included both observations in the foundry and, in some cases, consultations with foundrymen. Before entering, therefore, into the method of putting together different kinds of pattern work, it will be well to take a glance at the foundry, and examine the contrivances and the operations of the workmen, so that our operations in pattern work may be intelligently made from the beginning.

The floor of the foundry first demands our attention. It is composed of a layer of molding sand of sufficient depth to imbed patterns of the size usually cast in that foundry. For exceptionally large work, there is usually a place where the natural earth has been excavated to a greater depth; the cavity is filled with molding sand. This place is usually within easy reach of the crane (which commands almost every part of the floor) and the threshold of the melting furnace or cupola. We next observe the capacious oven for baking cores and drying molds for such special work as may require these operations; but the particular contrivance with which the pattern maker has now to concern himself is represented in Fig. 67. It is called a flask, and is composed of two or more parts (two only being shown in the engraving). The lower part is called the nowel, and the upper the cope. Each part is simply a strong rectangular frame of wood or iron. The sides, being continued past the rectangles, are roughly shaped for use as handles. The cope is provided with several crossbars, which embrace the pattern, as it were, being roughly shaped like it in contour and approaching

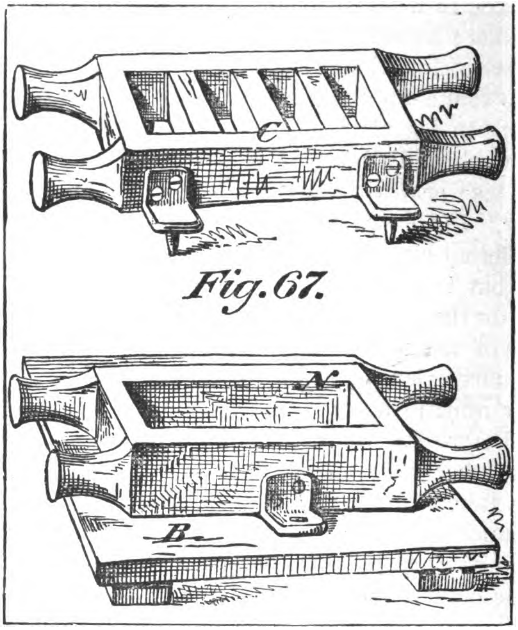
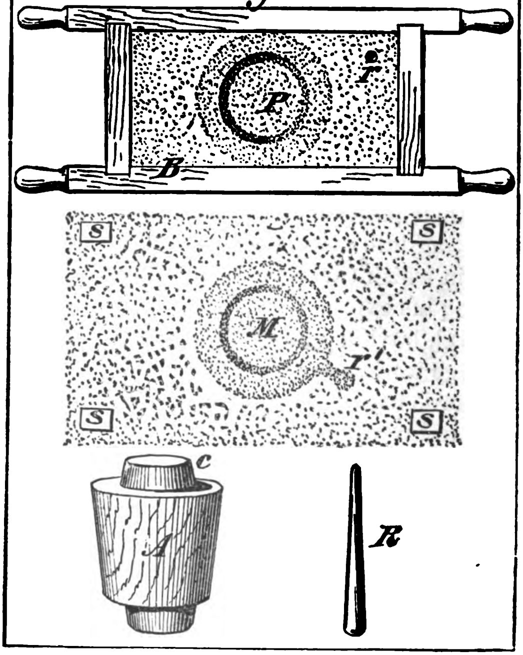


Fig. 67.

it in size, being about half an inch larger all round. These bars, by their adhesion, support the body of the sand in the cope, and in this they are frequently assisted by nails driven nearly half way into them. When an intermediate part is used with the two parts shown in Fig. 67, the contrivance is called a three-part flask; with two intermediates it is called a four-part flask, and so on. As the cope is provided with crossbars, so also the intermediates, having to lift a ring of sand, are provided with wings; that is to say, as much crossbar as will extend from the sides to within about half an inch of the pattern. The parts are guided, in their position one to the other, by taper pins on one part fitting into eyes fixed to the other part, as shown in Fig. 67, in which the cope is shown with the side having the two pins exposed to view, while the opposite side of the nowel, having one eye, is visible. In many cases, and for large work, the nowel is dispensed with, and the foundry floor is used in its stead, in which case the cope is guided to, and retained in, its place by stakes driven into the floor sand, as shown in Fig. 68, so that, when lifted to admit of the pattern being drawn from the mold, the cope may be returned to its exact proper and former position. In Fig. 68, A represents the pattern whose impression in the floor sand, at M, forms a part of the mold. B represents the cope; for the word cope is usually applied to the upper part of the mold as well as to that portion of the flask which contains it. The top print, C, of the pattern, has formed its impression in the cope at P. R is a round taper peg, which leaves a hole in the cope at *r*, through which hole the molten metal is poured. It also leaves an indentation at *r′*; and from this latter a gutter is made by the molder to communicate with the mold, M, as shown. The stakes referred to above are marked S. The dots, shown around the impression of the top pattern print, C, in the cope, are small holes made in the sand (after the molding is finished) by a piece of fine wire, and are for the purpose of giving vent to the air and gases which must escape when the metal is poured in.

Fig. 68.



It will be seen that, when a mold is made in the flask we have described, it can perform no further duty until the casting has been made; for every mold, therefore, we require a flask, and hence the pile of these appliances we always see in a foundry. For light work, however, a comparatively modern and greatly improved device has come into general use. It is termed a snap flask, each part having a hinge at one corner and a latch at the diagonally opposite one; so that, after the mold is made, it can be detached from the perfected mold and can be used to make another. Sometimes, though rarely, it happens that a casting is required of such form that the patterns cannot be constructed so as to be molded with a flask of the ordinary kind. The flask requires to come to pieces and the mold to be parted sidewise; this adds greatly to the labor of the molder, and the pattern maker should so construct the pattern as to avoid this, whenever he can devise any means of so doing. Even when the pattern is molded in the floor, the mold is sometimes of necessity made to part on one or more of its sides, and these partings are termed drawbacks.

By watching the operations of a molder, we shall observe that, in the case of a solid pattern—that is to say, a pattern not made in halves—he always endeavors to have as little of the pattern in the cope as possible, and in this respect the pattern maker should supplement his efforts. The reason is obvious: the cope has to be lifted while as yet there has been no opportunity to loosen the pattern in the mold. It is true that, in some cases, a bar is passed through the cope and driven into the pattern, and by rapping it the loosening is accomplished; but it is not well to have recourse to such an expedient, because, wherever the bar passes, the cope is damaged, and must be mended; and when a mold has to be mended, it is doubtful if the correct form, such as the pattern would have given it, will be left. Furthermore, it is all work in the dark; for the effect or extent of the rapping cannot be scrutinized, and it may therefore produce an undue distortion in one direction, while in another it may not have been effectual. Perhaps the bar may have descended at a place in the pattern where it is comparatively weak, from crossgrain of the wood or from some other cause. This measure is, therefore, on account of these difficulties, seldom resorted to; and it may be generally disregarded in the calculations of the pattern maker. The cope, then, being, as we may say, a dead lift, and with nothing to guide the operator in moving it, either horizontally or vertically, any part of the mold contained in it is much more liable to break down than is the other part of the mold. In extracting the pattern from the lower part of the mold, the eye lends to the molder great assistance. The pattern can be loosened in the sand before extraction, and is furthermore less cumbersome to handle than is the cope: all of which circumstances tend to preserve the lower part of the mold from damage during the extraction of the pattern. Rapping a pattern tends to alter the form of the mold from that calcu-

Fig. 69.

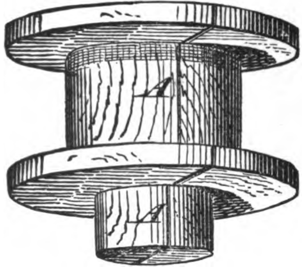
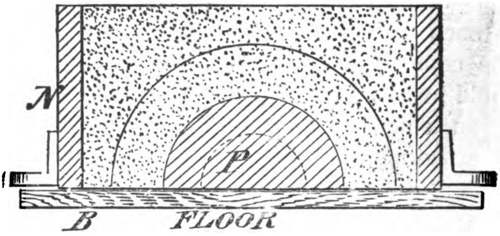


Fig. 70.



lated upon. A circle becomes slightly oval, a square becomes an oblong, and so on: and this cannot in most cases be avoided, because it is necessary to rap the pattern so as to enable the molder to extract the pattern without drawing out the sand with it; all that can be done in this direction is to rap the pattern as little as possible, and equally in all directions.

When a flask nowel is used, the labor involved in making a parting of the mold is facilitated. Fig. 67 shows a board cope and nowel for an ordinary straight parting; but it is evident that the parts of the flask may be made to show a crooked, a curved, or irregular line at the joint, if it is required, in which case the bed board must be made of similar conformation. The process of molding with a flask independently of the floor, is illustrated in Figs. 70 and 71. If it be required to mold the pattern illustrated in Fig. 69, which is made in halves, the joint being denoted by the line, A A, one of the halves is taken and laid with its flat face upon the molding board, B, shown in Fig. 70. The nowel, N, is then placed upon the board, so that the half of the pattern will be in about the middle of the flask nowel. Sand is then rammed tightly in the nowel; and when the latter is filled with the sand, it is turned upside down, showing the flat face of the half pattern, the rest of the half pattern being imbedded in the sand. The other half of the pattern is then placed upon the one in the sand, its proper position being determined and regulated by pegs fitting into holes, provided in the first part, to receive them. The next operation is to put on the cope, as shown in Fig. 71, the taper pins being fast to the cope lugs shown on the sides, fitting into holes provided in the nowel lugs, similarly shown, serving to hold the cope in position and prevent it from moving. The cope is then filled with sand, lightly rammed, the taper pin, R, Fig. 68, being inserted to leave in the mold the hole, R, Fig. 71, through which to pour the melted metal. The cope is now lifted vertically; and as the pattern is made in halves, the top half lifts with the sand in the cope. In some cases a screw is fixed into the top half of the pattern, the head of the screw projecting into the cope: the object being to insure that the top half of the pattern shall lift with the cope. The next procedure is to extract the two halves of the patterns from the molds, and perform any trimming or repairing that the mold may require, after which the cope is again placed upon the nowel, and the mold is complete, ready to have the metal poured in.

Fig. 71.

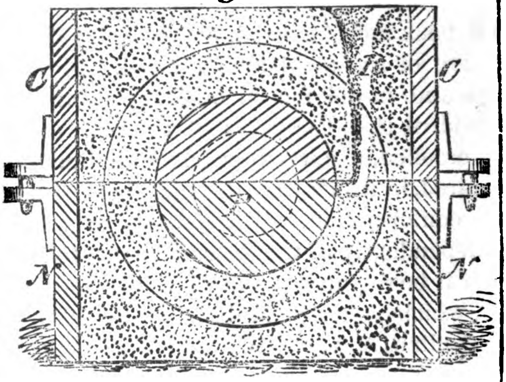
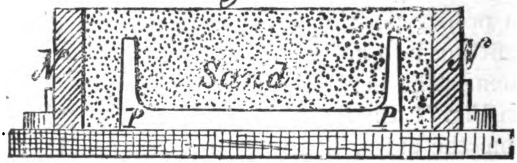
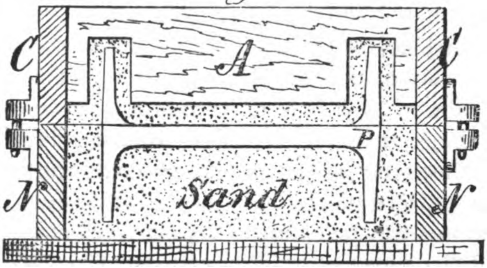


Fig. 76.



In Figs. 76 and 77, we have another example of flask molding, but for a pattern of different shape to our previous one. The pattern is, in this case, not made in halves, its flanges on one side being left loose. In Fig. 76, one half of the pattern is shown on the molding board, and the nowel placed thereon and rammed with sand; while in Fig. 77, the pattern is shown molded and ready to have the cope taken off, A representing one of the crossbars fitted into the cope, and following the outline of the pattern.

Fig. 77.



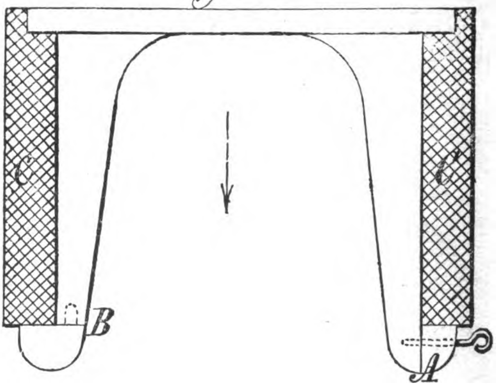
CHAPTER IV.

THE FOUNDRY.

ON CORES.

Cores are projecting bodies of sand, either left in the mold by the pattern itself or else made in a separate device called a core box. They are placed, after being dried, in position in the mold. The purpose of a core of the latter description is to leave a hole or recess of such a peculiar shape or in such a position that it is impracticable to make the mold of the necessary conformation by the use of the pattern alone. The use of these cores also permits us to modify the shape of a pattern that would otherwise be difficult to mold. For example, Fig. 78 represents

Fig. 78.



a plate of such length that it is necessary to mold it in the direction indicated by the arrow; as the pendants, which are long and narrow, with their projections at the extremities, would lock the pattern in the mold. Three methods present themselves whereby to overcome the difficulty. First, we may make the projection loose, the vertical line, A, being the joint; it is held in position by vertical dovetails or by horizontal wires, as shown in Fig. 78. In the latter case, the molder, when ramming the sand, withdraws the wires; and when the pattern is withdrawn from the mold, the two different projecting pieces are left in the mold, and are subsequently retracted horizontally, and then lifted out. It is obvious that this can only be done when there is sufficient space to accommodate the projecting piece as it is withdrawn from its recess in the sand, and to admit of its being raised to the surface. To this method there is the objection that the recess left by the projecting piece in the mold cannot be, in many cases, either inspected or dressed, if any reparation is required. A second plan would be to make the projecting piece join the pattern at the horizontal line, B, in Fig. 78, but separable from it; but in this case a three-part flask would have to be used, entailing double work for the molder. The third method is to affix the core prints, C C, to the sides of the pattern, leaving those sides smooth and even; and the pattern will then draw easily out of the mold. If we then core away all we have added to the pattern, as shewn by the dotted lines in Fig. 78, the casting will retain the correct shape of the pattern. To effect this coring away, we make dry sand cores of the shape of the core prints, C C, and place them in the mold. Ordinary dry sand cores are composed of a mixture of sand and flour moistened with water, and they are molded to the requisite shape in the core boxes already mentioned. They are then baked, becoming sufficiently strong to handle; but previous to the baking they are so weak that they cannot be handled without being in some way supported. It is, therefore, as great a consideration to the pattern maker how the core is to be taken from the box as it is how a pattern shall be drawn from the mold. We may divide cores molded in a core box into three classes: First, those that lie as they are made; second, those that require turning over; and third, those that not only require turning over, but require also a bed of sand made for them to lie upon during the process of baking. Figs. 72, 73, and 74 are examples of the first, in which the cores are represented by C. The core boxes, being made in halves and loose at two of the opposite corners, can be drawn away from the cores, C, leaving them standing, just as they were made, on an iron plate ready for removal to the oven. In a core box made as in Fig. 74, it is necessary to bore in the ends a couple of small holes for the insertion of wires to effect ventilation. In cases where suffi-

Fig. 72.

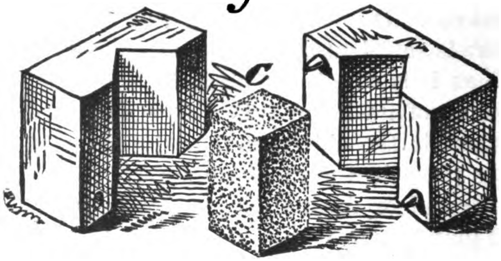
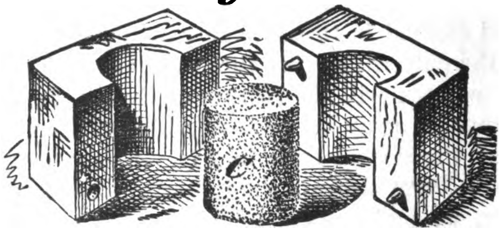


Fig. 73.



cient draft or taper can be allowed on the core, the core box need not be made in halves, but may be made solid, as shown in section in Fig. 75.

Fig. 74.

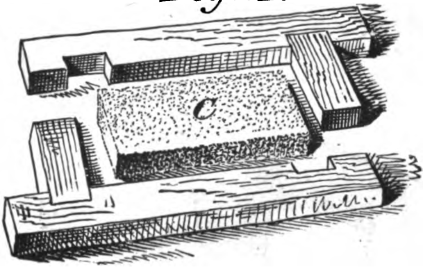
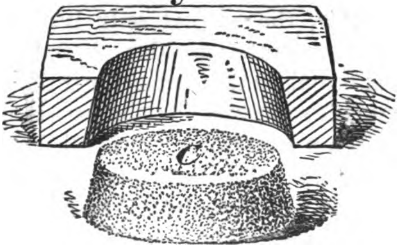


Fig. 75.



While it is the aim of the pattern maker to form his core boxes to work in the simple manner illustrated in our examples, there are very large classes of cores with which such easy methods are impracticable. This, for instance, is the case with all round cores that are of such length that they are not able to support themselves on end, and with those having branches, as shown in Fig. 79, which represents a core for a straight faucet. If it were attempted to make this core in a vertical position, its overhanging branches would fall away immediately after separating the two halves of the box; hence it is made horizontally, and generally in separate halves, which, after being baked, are pasted together and again dried, thus forming the full round core. In cases, however, where great numbers of such cores are required, as in steam fitters' work, they are usually lifted from the box whole; but it is a delicate operation, involving much practice. We need not, however, go into this, the subject only being mentioned to show how a pattern maker decides whether he shall make a full core box or only half a one; for if the halves of the core are to be made separate, and one part is exactly similar to the other, then a half core box is all that is necessary. Suppose, for instance, the core of a faucet, shown in Fig. 79, to be alike at the branches, C and D; then, it being made in two halves, meeting in a point represented by the line A B, the core box may be made to mold the half, E; and two of such halves, pasted together as described, will form the whole core. In this particular example, however, there is yet another way of making the core, providing the branches, C and D, are parallel in diameter, and that is, to punch holes in the main part of the core, through holes provided in the core box, using a piece of wood for the purpose.

Fig. 79.

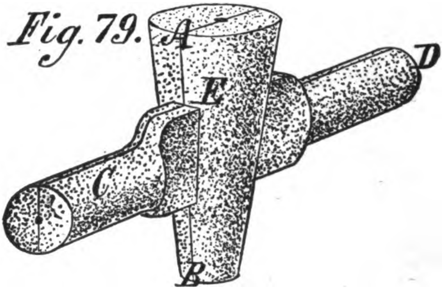


Fig. 80 is an illustration of a square core for a baluster; its four sides being curved, it is necessary to make it in separate halves, dividing it diagonally across the corners, as denoted by the lines A B, We have now to give an example of the third class of core, which will not stand on end and does not present a flat surface on any of its four sides, neither can it be readily divided, as in the former case. Fig. 81 is an illustration

Fig. 80.

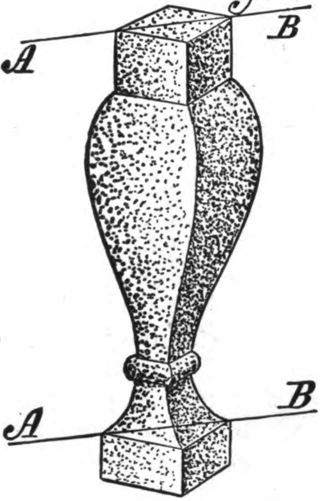
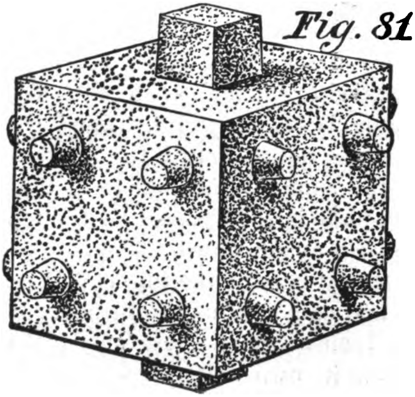
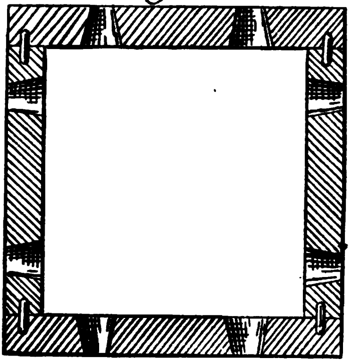


Fig. 81.



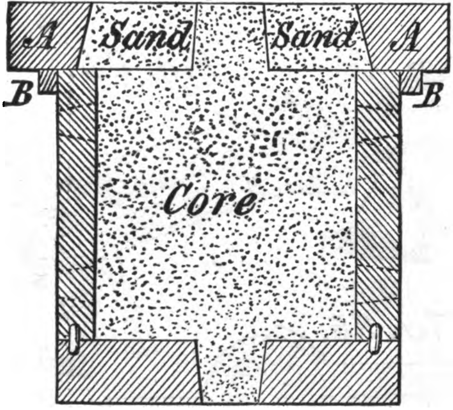
of probably the simplest kind of this class, which will require a core box that must part in all directions in order to enable us to extract the core, which will require, in addition to this, what is called a turnover box. Fig. 82 is an end sectional view of this core box, having four jointed sides and a bottom, with holes cut in them where the projections are to be formed on the core. The top, in this case, is simply two bars that cross the box where the projections occur; and holes are cut in these bars to form the projections. The box is retained together and kept in position by the taper pegs, shown at the junction of the sides. The ends of the box are recessed to receive the sides, but all is removable. In using this box, after ramming up the top, the crossbars are removed, and in their place is mounted the turnover box, shown in section in Fig. 83, at A, which is a simple square frame, made taper. It rests on the outer edge of the core box, so as to give a bed of sand somewhat larger than the core itself. Small blocks nailed to the under side, B B, keep it in position. The frame is then carefully filled with ordinary molding sand, so as not to disturb the projecting parts of the core, and the sand on the outside is then struck off level. An iron plate is then placed on the top of all, and the whole is turned upside down. The bottom of the core box, which has now become the top, is first removed, and then the sides and ends. Thus the turnover box affords a bedding of sand, on which the core may rest without suffering injury from its own weight.

Fig. 82.



It would be a costly matter to make core boxes for long cylindrical cores, such as are used for pipe and similar castings; hence, for such purposes, a core is made as shown in Fig. 84, in which C represents a core for a pipe, having a socket at one end. It is prepared as follows: Upon the two tressels, A A, is mounted the long tube, D D, which is perforated throughout its entire length with numerous small holes, and which is provided at one end with a crank handle, by means of which it may be revolved as it rests in the two rude V bearings, provided in the top of the tressels, as shown. Upon this tube a layer of rudely twisted straw rope, sufficient to make its diameter assume, from end to end, nearly the required diameter of the core, is coiled. Outside the straw rope there is then applied a coating composed of a mixture of loam and other material sufficient to increase the diameter from end to end, somewhat above finished size. To round up the core even, and make it of the necessary size, the core or loam board, B B, is employed. It is simply a board ranging in thickness

Fig. 83.



from seven eighths inch upwards, according to its length. One of the edges is cut to the conformation of the required core; and all but about three sixteenths of an inch of the thickness of this edge is beveled off at an angle of about 30°. This board is laid upon the tressels with the beveled edge uppermost, and is held in position by weights placed upon it over the tressels. The core is then revolved by the handle in the direction of the arrow, as shown in Fig. 85, in which A represents the tube, B the straw rope, C the loam coating, and D the board. It follows that, as the loam is added, the board will level it off, leaving the surface round and true, and to whatever shape the edge of the board may be made. It is customary to mix with the coating of loam, horse dung, or a substitute therefor, the object of which is as follows: It will be readily perceived that it is a difficult matter in a long casting to give vent to and permit the escape of the air and the gases formed in the mold by the molten metal; but by mixing in with the loam a combustible material, the latter becomes con-

Fig. 84.

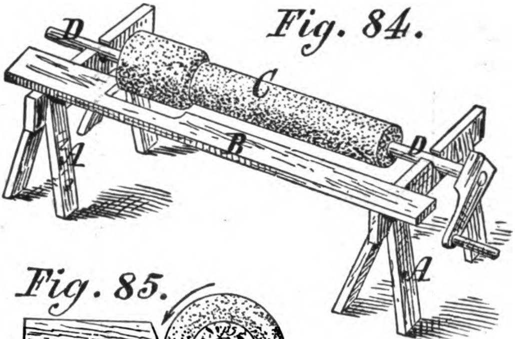
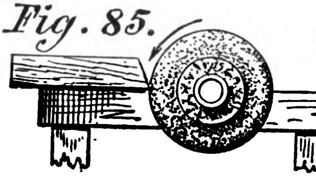


Fig. 85.



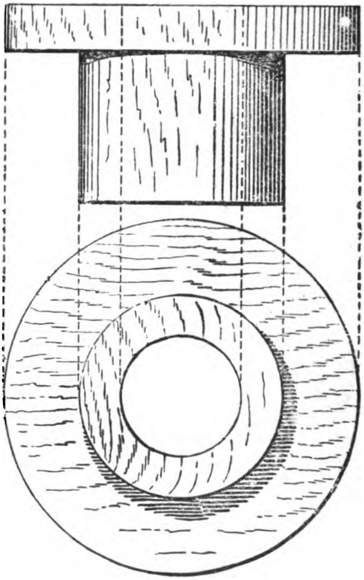
sumed during the baking of the core, leaving the latter porous, so that the air and gases can pass from the mold through the loam coating and thence through the straw rope, and find exit through the hollow tube upon which the latter is wound.

CHAPTER V.

EXAMPLES OF SIMPLE LATHE WORK.

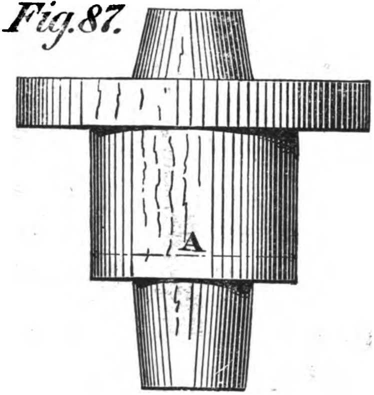
We may now commence a series of examples, accompanying each example with the explanations and considerations necessary to, and governing the method of, the construction chosen. Fig. 86 represents a drawing of a gland for which a pattern is required. Now this is a very simple pattern, and yet there are at least six different methods of making it, any of which may be followed, as will appear more clearly to the reader by his glancing over Figs. 87, 89, 90, 92, 93, and 94. The first question is how to determine which method is the most suitable. Let us suppose the pattern maker to be uninformed of the purpose the casting is to serve, or how it is to be treated: in such a case he is guided partly by his knowledge of the use of such patterns, and a consideration of being on the safe side. The form shown in Fig. 87 would suggest itself as being a very ready method of making the pattern; by coring out the hole it can be made parallel, which the drawing seems to require. The advantage of leaving the

Fig. 86.

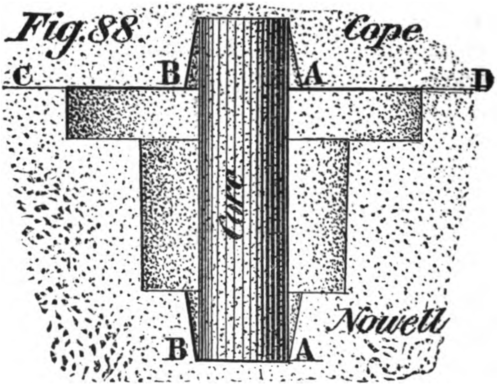


hole parallel is that less metal will require to be left for boring, in case it should be necessary; because, if the hole is made taper, the largest end of the bore will require to have the proper amount of allowance to leave metal sufficient to allow the hole to be bored out true, and the smaller end would, therefore, have more than the necessary amount: while just the least taper given to the exterior would enable the molder to withdraw the pattern from the mold. Made in this way, it would be molded as shown in Fig. 88, with the flange uppermost, because almost the whole of the pattern would be imbedded in the lower part of the flask, the top core print being all that would be contained in the cope; and even this many be omitted if the hole requires to be bored, since the lower core print will hold the core sufficiently secure in small work, unless the core is required to be very true. The parting of the mold (at C D, in Fig. 88) being level with the top face of the flange, much taper should be given to the top print (as shown in Fig. 87), so that the cope may be lifted off easily. Were this however the only reason, we might make the top print like the bottom one, providing we left it on loose, or made it part from the pattern and adjust to its place on the pattern by a taper pin; but another advantage is gained by well tapering the top print, in that it necessitates the tapering of the core print at that end; so that, when the two parts of the mold are being put together — that is to say, when the cope is being put in place — if the core has

Fig. 87.

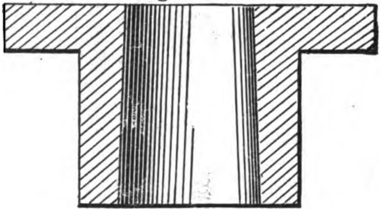


not been placed quite upright, its tapered end may still arrive and adjust itself in the conical impression, and thus correct any slight error of position of the core. The size of the core print should be, at the part next the pattern, the size of the core required; for if the extremities are made of the size of the core, and the taper or draft is in excess, there will be left a useless space around the core print, as shown in A B in Fig. 88, into which space the metal will flow, producing on the casting around the hole and projecting from the end face a useless web, which is called a fin, which will of course require to be dressed off the casting.



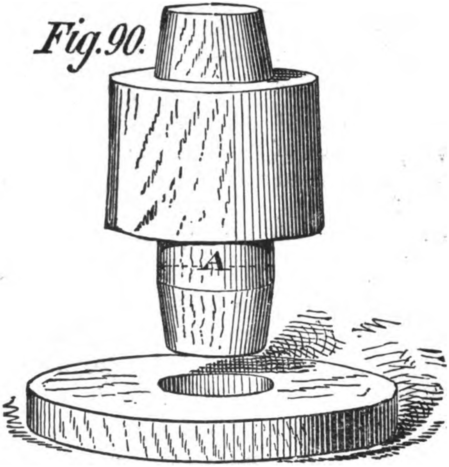
We will now suppose that our piece, when cast, is to be turned under the flange and along the outside of the hub or body, and that the hole also is to be bored. In this case the pattern made as above would still be good, but could be much more easily made and molded if it has to leave its own core—its shape being as shown in Fig. 89—because the trouble of making a core is obviated, and the core is sure to be in the center of the casting, which it seldom is when a core is used. We must, however, allow more taper or draft to a hole in a pattern than is necessary on the outside; about one sixteenth inch on the diameter for every inch of hight on work of moderate size is sufficient. The allowance for boring should be one sixteenth inch at the large end of the hole, providing the diameter of the hole is not more than five or six inches, slightly exceeding this amount as the diameter increases; whereas, if the pattern had been made with core prints, an allowance of one eighth inch for small, and three sixteenths inch for larger work would be required. These are the advantages due to making the pattern leave its own core. We have still to bear in mind, however, that, if the casting require a parallel hole, a core must be used; and furthermore, if the hole is a long one, we have the following considerations: The separate dry sand core is stronger, and therefore better adapted to cases where the length of the hole greatly exceeds the diameter. Then again, if the hole require to be bored parallel, it can be more readily done if the hole is cast parallel, because there will be less metal to cut out. The casting also will be lighter, entailing less cost, providing it has to be paid for by the pound, as is usually the case. The molder is given more work by making the core; but the saving in metal and in turning more than compensates for this, provided the length of the hole is greater than the diameter of the bore.

Fig. 89.

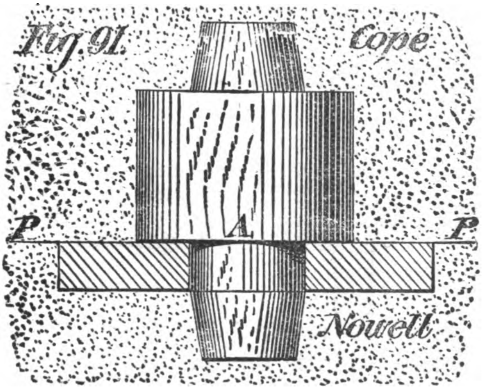


Let it now be required that the casting is to be finished all over, such as for a gland for a piston rod. It would in that case be preferred that, if the casting should contain any blow or air holes, they should not be on the outside face of the flange; and this will necessitate that the piece be molded the reverse way to that shown in Fig. 88—that is to say, it must be molded as shown in Fig. 90—with the flange downwards; for it may be here noted that the soundest part of a casting is always that at the bottom of the mold; and furthermore, the metal there

Fig. 90.

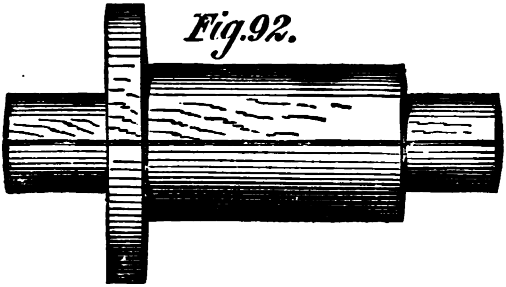


is more dense, heavier, and stronger than it is at the top, for the reason that the air or gas, which does not escape from the mold, leaves holes in the top of the casting, or as near to the top as it can—by reason of the shape of the casting—rise. The bottom metal also has the weight of the metal above it, compressing it, and making an appreciable difference in its density. It must therefore be remembered, that faces requiring to be particularly sound, should be cast downwards—or at least as near the bottom of the mold as they conveniently can. Following this principle, our gland will require to be molded as shown in Fig. 91, P P representing the line of the parting of the mold; so that, when the cope is lifted off, the loose hub, A, will rise with it, leaving the flange imbedded in the lower half of the mold. It is evident that in this case the pattern must be made as shown in Fig 90, the body and core prints being in one piece and the flange in another, fitting to an easy fit on to a parallel part on one end, and adjoining the core print, as shown at A.



For glands of moderate size, this method is usually adopted, and it answers very well for short pieces; but in cases where the length of the body approaches say three diameters, the horizontal position is the best, and the pattern should be made as shown in Figs. 92, 93, or 94. Even in short pieces, when the internal diameter approaches that of the external, this plan is the best, because it is difficult for the molder to tell when his core is accurately set in position.

Fig. 92.



For a pattern to be molded horizontally, Fig. 93 shows the best style in which it can be made. Its diameters are turned parallel; the required draft is given by making the rim of the flange a little thinner than at the hub, and by making the end faces of the hub and the core prints slightly rounding. If the hub is very small — as, say, a half inch or less, and the flange does not much exceed it — the pattern may be made solid, as shown in Fig. 92; but if the hub be small and the flange large, it should be made as shown in Fig. 94.

Fig. 93.

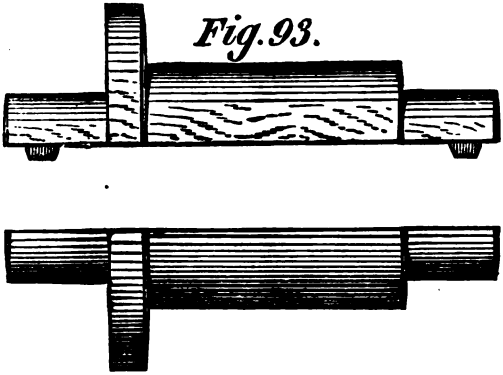
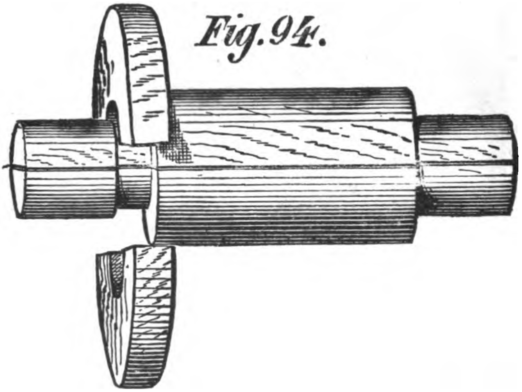
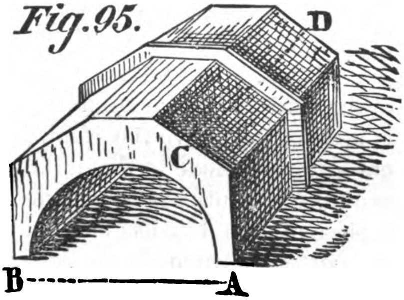


Fig. 94.



To construct the pattern shown in Fig. 87 we proceed as follows: From a piece of plank we saw off a piece of wood a little larger and thicker than the required flange, measuring with a contraction rule — that is to say, a rule specially made for the pattern maker, and having its measurements larger than the actual standard ones, in the proportion of one eighth inch per foot: so that a foot on a contraction rule is $12\frac{1}{8}$ standard inches, and an inch is $1\frac{1}{96}$ standard inches. The reason for this is, that when the metal is poured into the mold it is expanded by heat, and as it cools it contracts; and a casting is therefore, when cold, always smaller than the size of the mold in which it was made. Brass castings are generally said to be smaller than the patterns, in the proportion of one eighth inch per foot, and cast iron castings one tenth inch per foot; and so, to avoid frequent calculations and possible errors, the contraction rule has the necessary allowance in every division of the foot and of the inch. It is not however to be supposed that the possession of such a rule renders it possible for the pattern maker to discard all further considerations upon the contraction of the casting; because there are others continually occurring. Such, for example, is the fact that the contraction will not be equal all over, but will be the greatest in those parts where the casting contains the greatest body of metal. If we are required to make a pattern for a brass, such as shown in Fig. 95, its bore being six inches in diameter and its length ten inches, we shall find that the diameter of the casting will be less at A B than can be accounted for

Fig. 95.



on the basis of a contraction of one eighth inch per foot; and furthermore, the projection in the middle of the brass, which is sometimes provided instead of flanges to prevent the brass from moving endwise in the box, will cause the sides of the hexagon to cast hollow in their lengths; so that a straight edge, placed along the bevel from C to D, would touch the brass at each end, and not in the middle.

In the smaller sizes of patterns, however, such as those of 6 and less inches in diameter, there is another and a more important matter requiring attention, which is, that after a molder has imbedded the pattern in the sand, and has rammed the sand closely around it, it is held firmly by the sand and must be loosened before it can be extracted from the mold. To loosen it, the molder drives into the exposed surface of the pattern a pointed piece of steel wire, which he then strikes on all sides, causing the pattern to compress the sand away from the sides of the pattern in all directions; and as a result, the mold is larger than the pattern. In many kinds of work, this fact may be and is disregarded; but where accuracy is concerned, it is of great importance, especially in the matter of our example (brasses for journals), for they can be chipped and filed to fit their places much more rapidly than they can be planed, and it is necessary to have the castings as nearly of the correct conformation as possible. In cases where it is necessary to have the castings of the correct size without any work done to them, the shake of the pattern in the sand is of the utmost importance. If he is required to cast a piece of iron 3 inches long and 1 inch square, supposing the pattern were made to correct measure by the contraction rule, the molder, by rapping the pattern (as the loosening it in the mold is termed), would, by increasing the size of the mold above that of the pattern, cause the casting to be larger than the pattern: that is to say, it would be longer and broader, and therefore, in those two directions, considerably above the proper size, since even the pattern was too large to the amount allowed for contraction. The depth, however, would be of correct size, because the loosening process, or rapping, does not drive the pattern any deeper in the mold. It follows that, to obtain a casting of as nearly the correct size as possible, the pattern must be made less in width and in length than the proper size, to the amount of the rapping; and to insure that the molders shall always put the pattern in the sand with the same side uppermost, the word "top" should be printed on the face intended to lie uppermost in the mold. The amount to be allowed for the rapping depends upon the size of the pattern, and somewhat upon the molder, since some molders rap the patterns more than others: hence, where a great number of castings of accurate size are required, it is best to have two or three castings made, and alter the pattern as the average casting indicates. For castings of about 1 inch in size, the patterns may be made $\frac{1}{32}$ inch too narrow and the same amount too short; but for sizes above 6 inches, allowance for rapping may be disregarded.

In patterns for small cast gears, the rapping is of the utmost consequence. Suppose, for instance, we have 6 rollers of 2 inches diameter, requiring to be connected together by pinions, and to have contact one with the other all along the rollers: if we disregarded the allowance for rapping, the pinions will be too thick, and we shall require to file them down, entailing a great deal of labor and time, besides the rapid destruction of files.

To resume, then: having sawn out our piece of wood for the flange, we plane up one side, and set a pair of compasses to the radius of the required flange, and mark a circle upon the piece of wood, and then saw off the corners nearly to the circle. We then true up a facing chuck in the lathe, and fix the flange to it by screws passing through the chuck from the back, placing them far enough from the center to avoid their coming into contact with the hole which we shall require to bore in the flange. We then dress off the face of the flange to nearly the required thickness, using the gouge to rough it out with, and the scraping chisel to finish. It is not necessary to finish right down to the center, but merely down to a diameter somewhat smaller than the hole in the flange will be. Our next procedure is to mark the size of the hole, which is done by setting the compasses to the required diameter, and then holding them with one leg resting upon the hand rest; and by bringing the point into contact with the face of the work, we may describe upon the latter a true circle, somewhat smaller in diameter than that required. This circle will serve as a guide to us while we hold both compass points against the work to describe a circle of the correct diameter, which will be done by keeping the compass points at equal distances, one on each side of the circle first described. We must, in the last operation, hold the compass points lightly against the work until we can see that the line described by one point falls in the same line as that described by the other, and then we may make a deep mark. This method is quite as easy an operation as setting the compasses to the radius of the hole, and, putting one leg in the center of the work, describing a circle with the other; and this process is also more exact when the wood is rough. We next take a chisel of about $\frac{1}{8}$ inch wide, and cut out the hole at one cut, by forcing the chisel lightly through the thickness of the flange, taking care to cut the hole nearly $\frac{1}{32}$ inch too small, so as to allow finishing with the diamond point or side tool. The hole being finished, we may turn the outside diameter of the flange with a very sharp gouge, leaving about $\frac{1}{32}$ inch for finishing, which may be done with the scraper. When the scraping chisel — as indeed all scraping tools — is in proper order, a slight burr can be felt on the top face of the tool, which is caused by oilstoning the beveled face of the chisel last.

To form the body of the pattern, we take a piece of timber of sufficient size to make the hub and core prints in one piece, and, with an ax, we hack off the corners, so as to save lathe work. We then place it in the lathe between the centers, using the fork shown in Fig. 48 as the running center and to drive the piece of wood, and screwing up the back center sufficiently firm to hold the wood tightly. The large diameter is turned to its size with the gouge and scraper, using the latter to finish with, and bearing in mind that the wood is apt to become loose between the lathe centers, by reason of the latter becoming imbedded in the wood; and it is necessary, therefore, during the earlier portion of the turning, to try the back center and screw it up into the work, if necessary. Then, with the skew chisel, we cut two recesses, as shown in Fig. 96, the distance from A to B being the length of the body or hub of the pattern, and the small diameter of the recess being a little above the required diameter of the core prints. We next turn down the core prints to the required sizes, and turn the part shown at C, in Fig. 97, to fit the hole tight to the flange; and it will be perceived

Fig. 96.

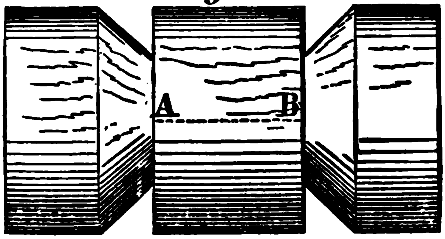
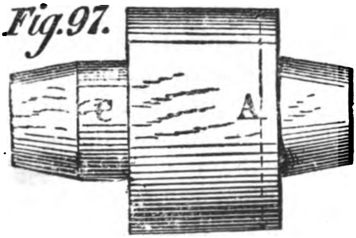


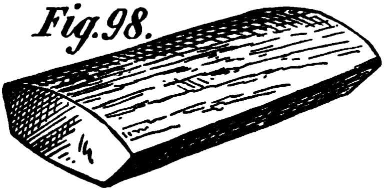
Fig. 97.



that, by leaving a longer end outside of the recess or nick at one end than at the other, we have left room for the flange, and so kept the core prints of equal length at each end, as shown in Fig. 97. The part that protrudes through the flange will in this case be for the top print, and it is therefore given an excess of taper, for reasons before explained. The hub or body of the pattern is also made taper, being a little the smallest at the end farthest from the flange (A, in Figs. 87 and 96), because this hub, being cast endwise, requires draft to permit it to be extracted easily from the mold.

Having brought our pattern, as nearly as possible, to the requisite size and form with the cutting tools, it is necessary to consider those final processes which so much add to the appearance and smoothness of pattern work. The first of these processes is termed sand-papering or glass-papering. Sand-paper is a sort of Will-o'-the-wisp to the beginner, luring him on to scamp his work, under the impression that sand-paper will hide the defects, and bring it all right, while the fact is nearer the reverse; for, let a pattern be ever so truly shaped and turned, if the sand-papering be injudiciously performed, the sharpness of its outline will be destroyed, and very likely its size and shape be seriously interfered with. It is true that it is scarcely possible to do much damage to large surfaces; but that is merely because of the great disproportion that would exist between an error engendered by sand-papering and the whole size of the pattern itself. If we have an inch cube to sand-paper, and should take $\frac{1}{64}$ inch more off one side than off another, our error would amount to the $\frac{1}{64}$ of the length of the pattern; but had the same thing been done upon a 12-inch cube, the error arising therefrom would only amount to $\frac{1}{768}$ of the length of the pattern. Again, to remove $\frac{1}{64}$ inch from one side of each of these respective cubes, we should have 144 times as much wood to abrade away in the one case as in the other; so that it will be readily perceived that the difficulties attending the sand-papering of a pattern, so as to preserve its true form and size, increase in a two-fold ratio as the size of pattern diminishes, until at last it becomes impracticable. Exactly where this point is reached, it is not possible to state; it will, however, vary with the capabilities of the workman, the steadiness of his eye and hand, and the nature and material of the work. It must have happened to many that they have made patterns so small that they dared not attempt to sand-paper them, and that they have turned intricate details upon a piece of work which could not be preserved in its sharpness under the abrasion of sand-paper. While, therefore, we respect sand-paper, let us respect our tools more, and let the pattern or core box, as the case may be, be brought as nearly to the form required as practicable with the cutting instrument, and then let the sand-paper be applied, not by folding it together and rubbing it upon the work, but by considering the shape we intend to finish, and preparing a piece of wood to correspond to the shape. Such a piece of wood is called a rubber. A flat surface requires a flat rubber, a convex surface a concave rubber, and *vice versa*. Rubbers are made of a size suitable to hold in the hand, and in length range up to 12 inches. Longer than this would be useless for one sheet of sand-paper, and that is all that is generally used at a time. Turned cylinders make good rubbers for core boxes that are semicircular, up to about 3 inches in diameter; above that size, the turned rubber becomes clumsy, and a piece flat on one side and planed to suit the curve is used. Such a piece is shown in Fig. 98.

Fig. 98.



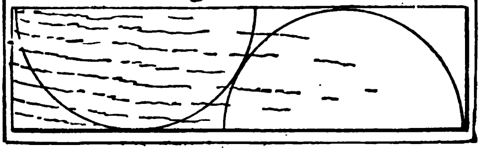
To use it, place one fold of sand-paper only around the rubber; and applying it to the work, move it over the surface of the work, and across the grain of the timber, if it is possible. If the size of the work is smaller than the rubber, we must take short strokes, so as to be able to move the latter steadily, and not round off the work at and toward the edges. A very good plan, where extra care is required, is to either glue the sand-paper to the rubber, or else fasten it with a few tacks. Sand-paper glued to a flat board is very useful for small surfaces; but in this case, we rub the work upon the paper, and not the paper upon the work. The grades of sand-paper used upon pattern work range from No. ½ up to No. 2, Nos. 1 and 1½ being most commonly employed.

The surfaces of the hub or body of our gland pattern being straight in their outlines, we sand-paper them in the lathe, with the paper wrapped once around a flat rubber, applying the paper lightly to the work, and moving it very slowly over the work, in the manner in which a file is used. We next fasten the flange to the body by gluing it, by using finishing nails, or by both. If finishing nails are used, care must be taken to use a bradawl before inserting the nails, for fear of splitting the wood.

To make the pattern in the manner shown in Fig. 90, the method of procedure is the same as the above, with the exception that the tapering of the core prints must be *vice versa*, as in this case the core print the farthest from the flange will be the top one in the mold, and must therefore be given the most taper. And since the body of the pattern will lift with the cope, while the flange will remain in the nowel of the flask when the mold is taken apart (as shown in Fig. 91), the flange of the pattern must be made an easy fit to its place on the body or hub, and must not be left of a tight fit, as in the former case. A pattern of the form shown in Fig. 92 may be turned, flange and all, out of a solid piece of wood; or, if too large for this, we may plane up a piece for the flange, and glue a hub to it; and when the glue is dry, turn up the whole pattern at one chucking in the lathe.

The construction shown in Figs. 92, 93, and 94 is so nearly the same, and the slight difference is so obvious, that an explanation of Fig. 94 will cover the ground. For Fig. 94 we plane up a piece over twice as long and more than half the size of the required flange, and out of this piece cut the two half flanges. If, however, the flange is of sufficient size to make it necessary to study economy, the two half flanges may be set out on the plank, lapping each other, as shown in Fig. 99. We next, with a flat scriber, draw a line on the chuck exactly through its center, and set the half flanges to this line, and then screw them to the chuck, and turn them as if they were solid. By setting the halves exactly true to the line, it is insured that the flange shall part exactly at the center.

Fig. 99.



To make the pattern shown in Fig. 93, we take two pieces of wood long enough to make the two halves, and allow about half an inch or an inch to turn off each end, so that the impressions of the fork and center may not appear on and disfigure the finished work, and for other reasons hereafter to be mentioned. We plane these pieces on one edge and on one face, making them of equal thickness. We make the flat surfaces which come together, true, trying them with the winding strips shown in Fig. 37, to detect any twist. Our next operation is to insert the pegs, and we may, for this purpose, adopt either of the two following methods, the more ready of which we will take first: Clamping the two jointed faces together, as shown in Fig. 100, we bore two holes right through the top piece and into the bottom, one to a little greater depth than the hight to which the pin is intended to project, as shown by the dotted lines. We then plane up a piece of hard wood, about two and a half feet long, to fit the holes tightly. It is just as easy to plane a long piece as a short one, and what is left over will serve for a future occasion. A useful tool for preparing pin stuff is illustrated in Fig. 101, which repre-

Fig.100.

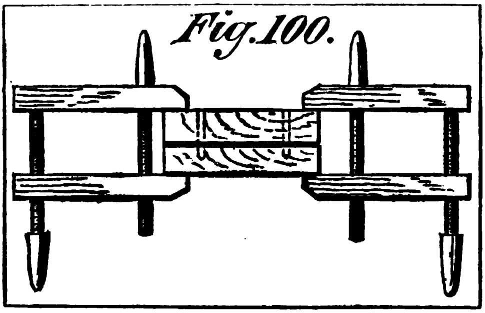
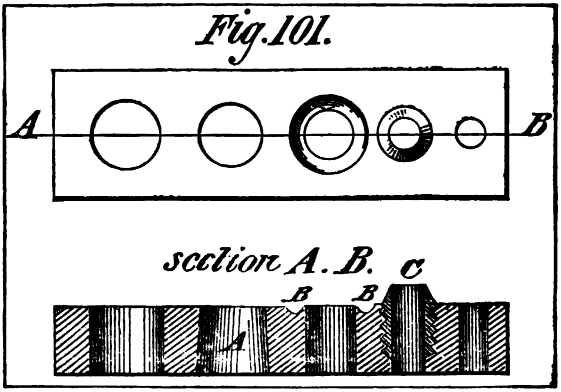


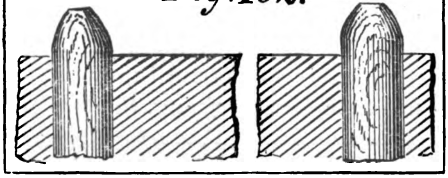
Fig.101.



sents a hardened plate of steel, pierced with holes of the sizes of the pins usually required. The wood for the pins having been planed up to the required size, is driven with a mallet through the plate, saving a great deal of time, and making the pins more nearly round than is possible by hand work. In some of these plates the holes are made taper, as shown at A, in Fig. 101; this, however, is detrimental, and the parallel hole is the best, because it guides and supports the stick, while it does not impede the cutting action of the tool. A hollow formed around the edge of the hole, as shown in the sectional view, at B B, would improve that action; or it might be still further improved by inserting bushes in the plate, with a portion left projecting above the plate and beveled off to resemble a chisel, as shown at C.

The pin stuff being prepared and inserted into one half of the pattern, the projecting end is then tapered off, as shown in Fig. 102. The formation of this projecting pin may seem a very simple matter; but if sufficient consideration is not given to it, a great deal of annoyance is caused to the molder, and the castings will be imperfect. If we reflect for what purpose these pins are inserted, we shall find the proper shape. First, with regard to the projecting length, some workmen seem to be guided by the diameter of the pin, making it project to a distance equal to its diameter; but it is obvious that a short peg or pin will govern the position as well as a long one, and will be less liable to stick in the loose half of the pattern: hence it is better to let the protruding end stand out from three sixteenths to one half inch, and let

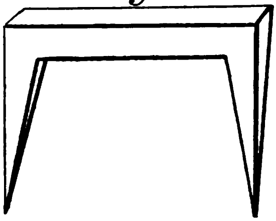
Fig. 102.



from one sixteenth to one eighth inch of the large part fit the hole, the nut being tapered off so as to be sure that the pin can be released easily. These conditions inevitably bring us to the parabolic form shown in Fig. 102. Another point to be observed is to make the pin of as large a diameter as is consistent with the work; for the larger the pin, the longer it will remain free from shake. Above all, it is essential that the pin be perfectly round at the part that fits the hole; and if these elements are neglected, castings will be produced of which the halves will not match, which is always very unsightly. Nothing is gained by making the pins to a tight fit in the loose half of the pattern, as they will not work that way; and the molder will enlarge the holes with a red hot rod, and then, after a little while, the charred part around the hole falls out, and the pin becomes too slack.

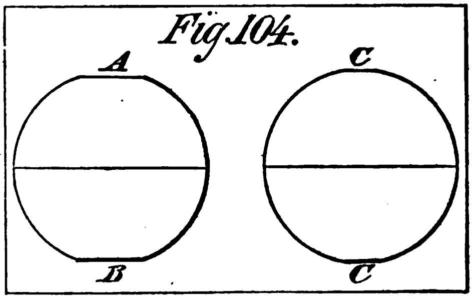
After inserting our pins, the two halves of our patterns are to be fastened firmly together; and this may be readily done by brushing the end faces with hot glue for a breadth of one half or one inch, according to the amount we have allowed our pieces to be larger than the finished work. Then we hold them firmly together with a screw clamp, leaving them until they are perfectly dry. If there is not time for the gluing, the two halves may be screwed together; and indeed, if the job be a heavy one, it will not be safe to trust entirely to glue, but to use screws or dogs. Dogs are a kind of square staple, made of steel, and of the form shown in Fig. 103; and two of them driven in each end of a pattern will hold its loose halves very firmly together. While very handy, however, on large or small work, they are

Fig. 103.



cumbrous; and the gluing or screwing is preferable. The work can now be mounted in the lathe, and turned as though it were solid. Care must be taken that the center points are exactly in the joint, and it was to ascertain if this was the case that our two halves were planed of equal thickness; for if, in the process of turning, one flat is seen to be narrower than the other, as shown in Fig. 104, at A B, it is proof that the centers are not in the joint; and unless the error is corrected, one half of the finished pattern would be thicker than the other. To remedy this error, we tap at the pattern lightly with a hammer in the required direction, and then screw up the lathe centers a little more, continuing the process until the flat sides upon the pattern, when very nearly trued up—as shown in Fig. 104, at C C—are equal, and finally disappear simultaneously.

Fig. 104.



Our pattern being then turned and sand-papered, as already directed, the next proceeding is to stop up all holes or cracks that are not desired to appear, with either beeswax or putty. This is a simple process, but it may have been noticed that some workmen take a much longer time over it than others, at least when beeswax is the stopping material. One who is expert at this work guesses just the proper amount necessary for each hole or crack; then he forms the wax into a worm-like shape, and with a warm chisel (that is not hot enough to make the wax run but only to cut it easily) he presses the wax into the hole, and seldom leaves any surplus to remove. The same knack is necessary in filleting, that is, in filling in an internal square sharp corner, when it is thought too small to be filled in with wood; for if the worm or string of wax of the right size be laid along the corner, the pressure of a warmed gouge will cause it to expand to the required fillet; while if too much wax is inserted, much time will be occupied in trimming off the surplus.

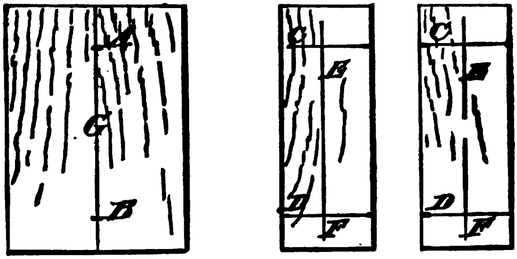
The third and last of the finishing processes is the application of two or more coats of spirit varnish, which adds to the appearance of the pattern, and increases its durability by giving it a surface impervious to water, and by producing that smoothness so necessary for its easy extraction from the sand. A varnished pattern escapes much of the rough usage commonly bestowed upon patterns, because the molder does not rap it so much as he otherwise would do. Several thin coats of varnish give a much finer appearance than fewer and thicker ones. The first coat fills up the pores of the wood and fixes the fibrous projections left by the sand-paper; and after the first coat is dry, fine sand-paper is again applied to remove the fibers so fixed. The second and succeeding coats give the gloss.

The pattern maker invariably mixes his own varnish, which he does in the following manner: The varnish pot should be of stone, and not of iron, which would discolor the varnish. The cover should be of thick leather, having through the middle a hole of such size that the brush handle, forced through it, will be suspended, and will not pass through to the bottom of the pot. The object of making the cover of leather is that the varnish collects around the lid and sticks the cover down, requiring sometimes so much force to remove it that wood would be liable to split. In the pot is placed so much shellac, and there is added just sufficient alcohol to cover the shellac, the whole being occasionally stirred with a piece of stick, and not with the brush. The consistence should be that of raw linseed oil; and to hasten the mixing, a little warmth may be applied.

The color of the varnish used is, strictly speaking, optional. The usual plan, however, is to use clear varnish for the pattern, and black for core prints and the insides of core boxes, which thus distinguishes them. The black is made by adding the best dry ivory black to the clear varnish. A very durable varnish may be made by adding powdered oxide of iron to the clear varnish, which gives a hard varnish with a reddish brown color. In mixing colored varnishes, however, we must remember, that the lighter the pigment, the easier they work. Ivory black is the lightest pigment, and so always pervades the varnish, and does not readily settle to the bottom; hence it does not often require stirring. Oxide of iron requires frequent stirring, even in the course of varnishing one pattern, if it be a large one; because it settles so rapidly that a perceptible difference in the coat is apparent, unless the varnish is stirred previously to each insertion of the brush. The brush should never go to the bottom of the pot, and the pot should always be kept covered when not in actual use. Varnishing lathe work cannot be done while running the lathe; but after the work is varnished, running the lathe hastens the drying. Work should always, if possible, be varnished on a dry day; for if the air is damp, the varnish becomes what is technically termed chilled — that is, it assumes a soapy or milky appearance, as though it had absorbed water — and hence is spotty when dry.

Having thus finished our example, we may now explain the process of putting pins in patterns, which we omitted to do when speaking upon that subject, to avoid digression. There are many cases in which it is not suitable for the pin hole to show on the outside of the pattern; and again, in large work, the holes would require to be bored so deep, and the pins made so long, that it would be too elaborate an affair altogether. In such circumstances, lines are resorted to, being drawn in the following manner: Place the pieces side by side, with the planed edges touching and the ends fair, as shown in Fig. 105, the line, G, representing the edges; and make two fine notches at A B. Then separate the pieces, and square the very fine lines, C C, D D, across with a knife. Then set a gage to half the width of the pieces, and mark the intersecting lines, E F; and the centers for the respective pin holes will be the intersection of the lines, C E and D F. If, however, we have no planed edge to work from, and the job is of such size as to involve so much labor as not to admit of planing, we may take two small brads or finishing nails (or as many as we desire to have pins), and drive them almost entirely into one piece of the wood, in the spots where the pins are ultimately to be, and then file the projecting part of each to a point. By then resting the other half in its proper relative position upon the filed points, and, when adjusted, applying a little pressure to it, the nail points will enter the top piece and mark the corresponding centers for the holes to receive the pins. We may then extract the brads or nails, and proceed to bore the holes and insert the pins.

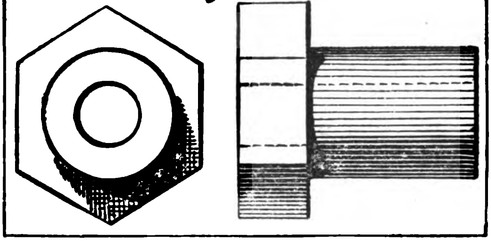
Fig. 105.



Another method of marking the pin holes, is to provide some ordinary lead shot, and make shallow holes with a brad-awl, slightly less in diameter than the shot. Where pins are to be inserted, place the shot in the hole, so that they project beyond the surface, and then proceed as described for the brad points—the latter being the more expeditious method of the two.

Our second example, Fig. 106, is a design for another kind of gland, such as is often fitted to glands for pump rods and spindles. For the small sizes, the glands are usually cast solid, and the hole is drilled out in the lathe;

Fig. 106.



in which case, providing the gland is not very deep, it would be molded vertically, with the head in the nowel, and would be turned out of the solid piece of wood in the style of our previous example, treating for the moment the hexagonal part as a flange, whose diameter must be turned to the size of the hexagon across the corners. After the turning is done, we mark the hexagon as follows. We set a pair of compasses as nearly as possible to the radius of the turned piece that is to form the hexagon, and divide that piece off into six divisions, in the manner shown in Fig. 107—for the radius of a circle will divide its circumference into six equal parts—so that, if the compasses are correctly set, one trial will be sufficient; but if not, we must readjust the compasses, and go around again. Then, from these points, we square lines, as shown in Fig. 107, at 1, 2, 3, 4, 5, 6; and then, with the paring chisel, we pare off the sides to the lines. It is not necessary to actually draw the hexagon on the circumference, by joining the lines of division on the top of the flange; for a straight edge being applied as the paring proceeds, will be all that is necessary to produce a true hexagon. Nevertheless it is possible that error may have crept in, though we have performed the above operation with the greatest of care; it is therefore imperative upon us to apply correcting tests to our work, such as a pair of calipers, to try if each pair of the opposite sides are parallel; also the bevel, to verify if each angle of the figure contains 120°. Hexagon shapes are so common that a special hexagon gage is very useful; and such a gage, of the most approved form, is shown in Fig. 108, together with its method of application, the edges, A B, being to try the hexagon, and C D to square the edge to

Fig. 107.

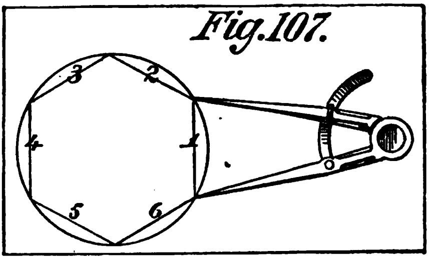
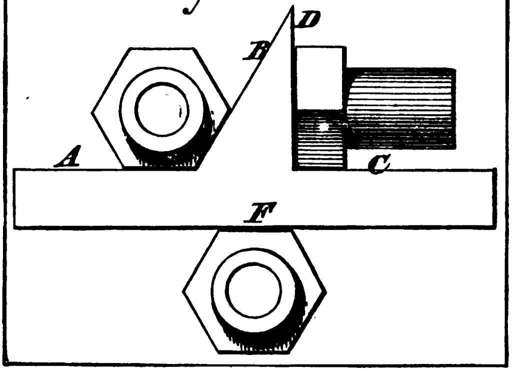
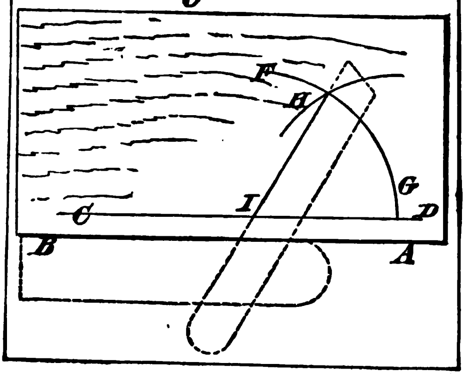


Fig. 108.



the face, and the edge, F, being used as a straight edge. If, however, we have not such a gage, we may set the bevel square, shown in Fig. 23, in the following manner: Take a piece of board, planed on one side and on one edge, and let A B, in Fig. 109, represent the planed edge, from which we mark with the gage the line, C D. Then taking any point, such as I, in the line C D, as a center, at a convenient distance, we describe with a pair of compasses the arc, F G. We then take the compasses, and, without shifting their points at all, we rest one point on the intersection of the lines, C D and F G, and then mark the arc, H. If then we draw a line from the intersection of the arc, F G, and the arc, H, to the center, I, upon which the arc, F G, has struck, the lines, H I, I C, form the angle required; and we may apply the stock of the bevel square to the planed edge, A B, and set the blade to the line, I H, as denoted by the dotted lines. The bevel being set, we test the work as it proceeds, first cutting down one hexagonal side, and then applying the bevel to gage the angle of the others; and as the diametrically opposite sides are finished, we apply the calipers. The lines of division upon all good pattern work are made very fine, in fact, merely distinguishable; and the instrument by which they are drawn is shown in Fig. 110. It is called a cutting scriber, and the end at A is beveled off at both sides, like a skew

Fig. 109.



chisel, forming a knife edge. The end, B, is ground to a point, and both ends are finished on an oilstone. The point end is for drawing lines along the grain, while the cutting edge, A, is for drawing lines across the grain of the wood. The wooden handle in the center is to enable the operator to hold it more firmly. It sometimes happens that the size of the hexagon is given across the flat sides instead of over the angle; and when that is so, we proceed as follows: We describe upon a piece of board, as in Fig. 111, a circle of a diameter equal to the given distance between the flat sides. We then take a hexagon gage, or else set the bevel square to an angle of 120°; and applying it to the planed edge of the board, we draw the line, C D, in Fig. 111, in which figure A is the circle of the size of the flat sides of the hexagon, and B E are the planed edges of the board. We next reverse the bevel; and from the opposite edge of the board we strike the line, F D, cutting C D at the point D, where both the lines cut the circumference of the circle, A. Then from the center of the circle A, we draw the

Fig. 110.

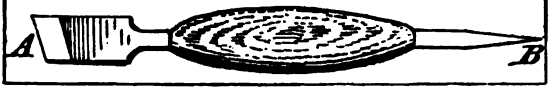


Fig. 111.

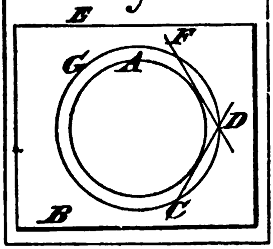
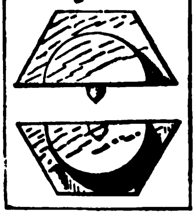


Fig. 112.



circle G, intersecting the point D. The diameter of G will be the size of the hexagon across the corners.

If the gland is a long one, it will be better to make it in halves, letting it part across two corners, as shown in Fig. 112. When a gland of this kind is made in halves, the corners at the parting are liable, from their weakness, to chip off, and it is therefore proper to make it of hard wood.

CHAPTER VI.

EXAMPLES OF T PIPE AND JOINT WORK.

OUR next example is what is called a T, a drawing for which is shown in Fig. 113. It is shown with flanges on the main body, and a hexagon on the branch. Sometimes a flange is employed instead of the hexagon, but this depends upon the connections to which it is to be attached. Patterns of this class are often made so that either round flanges or hexagonal connections may be put on at will; and it is in that style that we propose to make our example. It is apparent that the pattern will be the most easily molded with its body and branch both lying horizontally in the mold; so that, if we suppose the surface of this paper to represent the surface of the mold, the engraving shows just how the pattern will lie in it. It will be advisable, therefore, to make the pattern in halves.

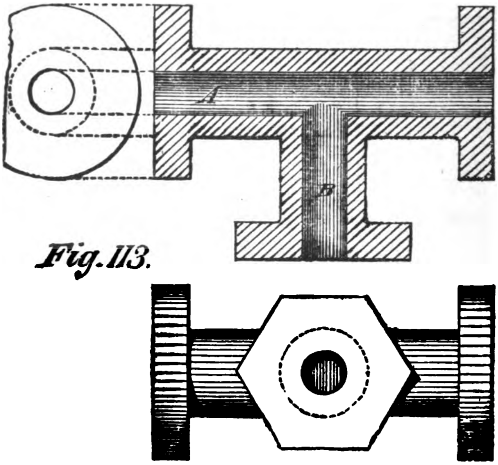


Fig. 113.

We first prepare the body and flanges, in the same manner as described for the body of our gland; the only difference being that we have, in this case, to fit a flange on each end. The same method is pursued in making the branch, with the exception that we only require a core print on one end, the other end abutting against the body. The first question that arises is, How long shall we make the branch? and this depends upon how far the branch follows the curvature of the body. In our example, the branch and body are of the same diameter, and therefore the branch will follow exactly half way around the body. We turn up the branch piece, then, to its requisite diameter, and make its length equal to the diameter to which it should stand out from the body, added to half the diameter of the body. The pieces we have made, then, are those shown in Fig. 114, in which A represents the piece for the body, and B, the piece for the branch. Our next proceeding is to cut out the abutting end of the branch to fit to the curvature of the body, and this we perform as follows: We first set the bevel square to an angle of 45°, by the process shown in Fig. 109, and then, taking the branch halves apart, and

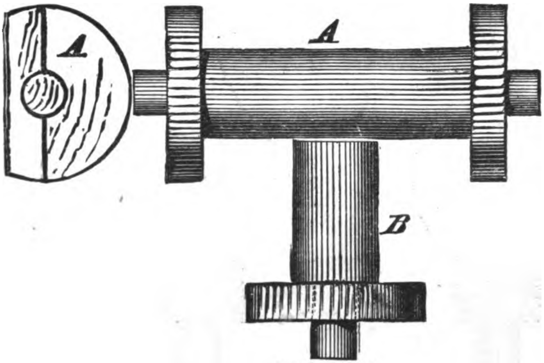
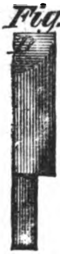


Fig. 114.

placing the bevel square with its back across the end face of the branch (the blade lying on the joint face of the half branch), we mark the two lines, A B, in Fig. 115, which must meet exactly in the center of the branch and at the extreme end, as shown in Fig. 116. We then pare off the angular piece, C D, down to the lines, A B. If, before we do the paring, however, we give our half branch a quarter turn around, it will appear as shown in Fig. 116; the curve formed by the intersection of the plane surface (just made) with the round surface of the piece, is the true curve of the body of the T.

Fig. 116.



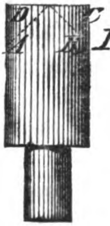


Fig. 115.

Turning to the other half of the branch, we perform upon it the same operation; and we may then cut away with the gouge the intervening timber from between the curve lines. Our two halves will be of the proper curve at the end, to fit exactly to the body of the T, as shown in Fig. 117, in which A represents a sectional view of the body of the T, and B C are the two halves of the branch; while the view D shows the body of the T lying horizontally, with the branch attached.

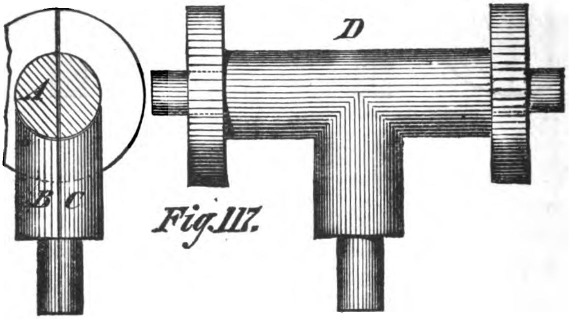
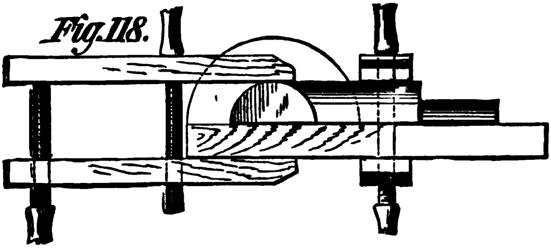


Fig. 117.

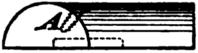
We have now to fasten the branch to the body of the T; and here we must pause to consider whether the pattern is required to serve simply for the production of a few castings; whether it is to be cast aside after the first casting, never to be used again (which is often the case), or whether it is intended for standard or continuous use. For a temporary purpose, a few screws will be sufficient; but for a permanent pattern, a much stronger joint may be made as follows: Brush with hot glue the ends of the branch piece, and let them stand until the glue has been absorbed into the pores of the wood. This is called sizing, and is always necessary in gluing end wood, as it is called—meaning the end grain of wood. The reason that sizing is in that case necessary is, that the pores of the wood all meet the surface in the end grain, and the sizing is necessary to fill them. We then take a truly planed piece of board, and lay one half of the body down upon it, placing a piece of thin paper between the body and the board, so that any glue that may run out may not touch the board: otherwise it may glue the work so fast to the board that, in parting them, some of the fibers of the wood may get torn out. Then we fasten temporarily the half body to the board, and lay one half of the branch with its flat surface on the same board, and glue it to its place, drawing it well up to the body piece with dogs or clamps, at the same time observing that it is close down to the board, and fixing it temporarily there, as shown in Fig. 118, and allowing it to remain until the glue

Fig. 118.



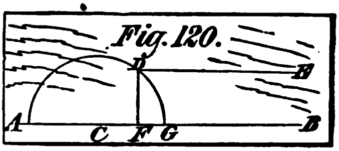
is dry. In putting on the second half of the branch, the board need not be used, since the first half, already in position, will serve as a guide. A piece of paper must, however, be placed between the two halves of the branch, to prevent them from adhering together. When all is dry, put a strong screw in the position denoted at A, in Fig. 119, cut out a recess on the flat face of each half, and let in a piece of hard wood, as shown by the dotted lines in the same figure.

Fig. 119.



Let us now suppose that, in our example, the diameter of the branch had been smaller than that of the body of the T. In that case we must first ascertain its proper length by the process illustrated in Fig. 120, which represents a piece of board, upon which we strike the line A B; and from the point C, we make the semicircle D, which must be of the same radius as the body of the pattern. Then, parallel with the line A B, we draw the line D E—the distance between these two lines being equal to half the diameter of the branch of the pattern. Then from the junction of the line D E with the semicircle D, we strike the line D F, at a right angle to A B; and then from F to G, added to the distance which the branch requires to stand out from the edge of the body, is the length we require to make the branch.

Fig. 120.



To draw the curve on this branch so as to cut it out to fit the body, we proceed as follows: Fig. 121 represents the application of a peculiar trammel, designed for this and similar purposes. It enables the operator to strike a true circle upon a round or uneven surface. It is composed of the turned bar or rod of metal, A, of about half an inch diameter, and upon it slides the piece of brass tube, B, upon which is contrived a support for the sliding arm, C, as well as a set screw for fastening the arm, C, in any desired position. At the end of the arm, C, is placed an arrangement for fastening the scriber, D, so that we may set the scriber at any requisite distance from the rod, A, by adjusting and fastening the arm, C, and revolve it about while lifting or lowering it upon the rod, A. When properly made, this is a most useful tool; and if not in use, it may be taken apart in an instant, and it occupies but very little room in a tool box. If the stand, E, pierced with holes for screwing down, is provided, it will be a very useful addition, but it may be dispensed with; whereas the tool proper, or some improvised substitute for it, is absolutely necessary, for the curve must be struck somehow. If the pipe or branch is large—say even six inches in diameter—to attempt to fit it by guessing and trying, is the work of a novice and not of a workman. To apply this tool to our branch, we proceed as follows: Taking a planed board, we gage a line upon it, and at a point on this line we describe a circle upon it of the size of the foot of the instrument. We then make two V blocks, such as shown in Fig. 122, to carry the branch. We then place these V blocks with the apex of the V exactly over the gaged line, and place the branch in the V's. We then set the point of the scriber at a distance from the rod of the trammel equal to the dia-

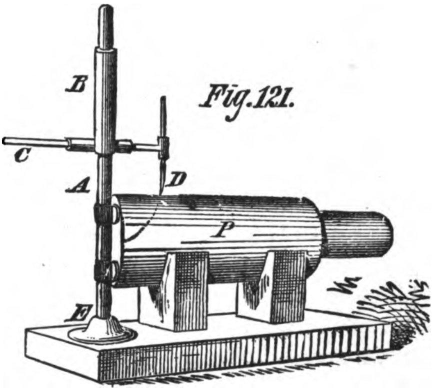


Fig. 121.

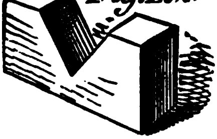
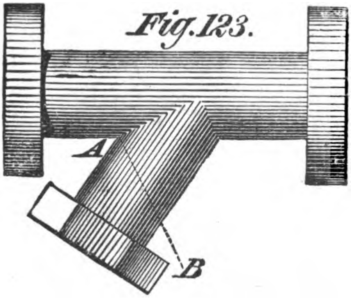


Fig. 122.

meter of the branch, which may be readily done if the size of the rod be known. We next mark upon the top of the branch, as it lays in the V's (with the joint of the two halves standing vertically), the distance it requires to be cut out to form the curve, which distance will correspond to the distance of F G, in Fig. 120. We then draw the branch forward, until this mark falls exactly under the scriber, keeping the joint faces vertical; and this adjustment being made, we fix temporarily the branch to the piece of board whereon it and the V's rest. Then we move the arm, C, in Fig. 121, a half circle; and letting the point of the scriber contact with the branch, we draw the necessary line. It will be found, however, that it is requisite to mark the lines while lifting the arm, to prevent the scriber from digging into the wood. Thus one side of the branch will be marked, and we must then turn it upside down on the V's, set the joint vertically again, adjust the mark to the scriber point, and proceed as before to mark the other side of the branch. We may then cut out the corners to the lines, which may be most rapidly performed by a band saw, sawing exactly to the line—the branch being held on a board, as it was when being marked. In fact, a piece of wood should be fitted underneath, where the saw cut will come, so as to prevent the fibers of the wood from being torn out at the edge, showing a ragged cut—as it is very apt to do, especially if the band saw is not in first-class order.

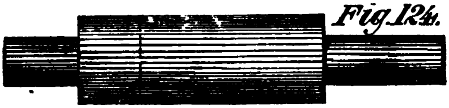
Fig. 123.



Should the branch be required to stand obliquely to the body of the pattern, as shown in Fig. 123, it may be struck out in the same manner; but instead of being set square with the rod of the trammel, as in the former case, it must be set at the bevel at which it is to be fixed upon the body of the pattern. When marking one side, the branch must make an angle with the upright equal to the angle at A, in Fig. 123; while, when marking the other side, it must form an angle equal to that at B, in the same figure. It will pay, where two or three pattern makers are employed, to have this marking apparatus always standing ready for use upon a board, with the degrees of angles marked thereon; so that a workman could mark off his job in five minutes, and cut it out with a band saw. Cutting out with a gouge, and trying to its place, may take four or five hours. It must be borne in mind that too much care cannot be given to striking out the piece accurately, and to sawing them true to the lines. The saw must be sharp, and of a width suitable to the curve, and not tremble, or "dither," as band sawers say. By attending to these matters, a fit may be obtained with a minimum of labor to the workman; and this is desirable in itself, and is an item of profit in the cost of the pattern.

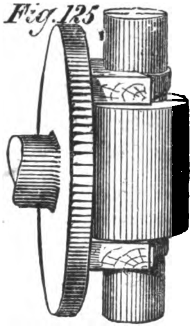
We need not dwell upon the half core box, which is necessary for this pattern if the branch stands at a right angle to the body; or the full one, necessary if it is required to stand obliquely. When the body of the T is much larger in diameter than is the branch, we may joint the two in a simpler way, which, so long as it does not entail a great weakening of the body, will be found more advantageous than the method described. This simpler method is: Having found the amount of the length of the branch necessary to allow for curvature of the body (by the process shown in Fig. 116), we turn upon the branch end an additional projection or stem, as shown in Fig. 124, somewhat smaller

Fig. 124.



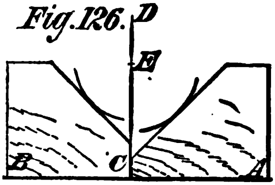
in diameter than the branch itself; and we then cut in the body a recess to receive the branch and turned stem or projection, which recess may be either cut out with a gouge or turned out in the lathe, the latter being, for obvious reasons, the best method. For this latter operation, we take a chuck, similar to that described in Fig. 58, as a cement chuck; and having verified that the point and the face of the chuck run quite true, we draw a center line across it, set the apexes of the two V blocks exactly over this line, and then fasten them. Having marked upon the body the center of the branch, we find a point diametrically opposite to it upon the body, and place the body so that the steel center point enters the point so found, at the same time as the body rests in the V's. We then fix it in this position by thin straps of hoop-iron, or any other contrivance that will not project so as to prevent the lathe rest (or tool rest, as it may be more properly termed) from being brought close to the work. The work must be securely screwed to the chuck, on account of the high velocity of the lathe in turning. To cut out the recess, we commence by placing a center bit in the back lathe center, and boring a hole, as large as convenient and very nearly to the required depth. A screw bit is not available for this purpose, for it would in many cases be right through the work before there was time to stop the lathe, which is not usually sufficiently under control. We may next take a turning tool, and turn out the recess to fit the end of the branch; and after taking the job from the lathe, we fasten each half of the branch by gluing and screws. In connection with this method, there is yet another advantage: it is, that by cutting away the body instead of the branch, it renders us indifferent as to

Fig. 125



whether the shape of the body be spherical, as in a globe valve, or elliptical, or even vase-shaped: because, in this case, the shape adds nothing to the difficulty of the job. Should it occur that one end of the T is larger than the other, we may find the height necessary for each of the V pieces (whereon the body rests during the turning process) as follows: Draw upon a piece of board the line A D, in Fig. 126, which will represent the plane of the chuck; and let the point C represent the center point of the lathe. Then, from C, we square up the line D; and we set the compasses to the radius of the body of the pattern at the center of the place where the branch is to be. We take a radius from C, and about $\frac{1}{16}$ inch up from the line A B, and with this radius we mark on the line D, the point E. From this point, as a center, we strike the axes, E and F, whose radii correspond to the unequal sizes of the pattern, where the V's are required to be. Then we draw tangents to each of these arcs, and complete the forms of the V blocks, as shown in Fig. 127, in which half of each V block is shown.

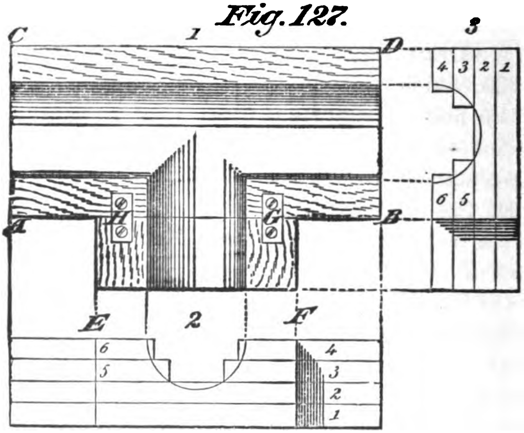
Fig. 126.



We have now to make a core box for our T; and for clearness of illustration we will make the drawing somewhat larger than those for the T itself. Fig. 127 represents three views of the core box; that portion which projects below the line, at B, may be made separately, and need not, therefore, be given any consideration. Having drawn the plan of the box, as shown in Fig. 127 at 1, we draw the end and side views, as shown at 2 and 3, and divide these latter into courses of a thickness to suit the stuff at hand, from which the core box is to be made. The courses may be made of equal or unequal depth. Courses 1 and 2 are got out of the full size of the box, while courses

3 and 4 must be of the length of the box, but their width will differ according to the curvature of the half circle of the core, as shown in Fig. 127, at 2 and 3; 5 and 6 will be similar to 3 and 4, and may be marked from them. All

Fig. 127.



these pieces must be planed to a true surface and glued together, each course being allowed to dry before the next one is put on; but for greater expedition, nails, in addition to the glue, may be used, in which case care must be taken that they do not come so close as to interfere with the cutting out of the half circle. The part A B, if very short, say under 3 inches, may be made in one piece; but if over 3 inches and not over 6 inches, we take two pieces of the required length and width, and of half the thickness, and chuck them in the manner previously explained for making flanges in halves; then we place the work in the lathe, and bore a hole for the core, then take them from the chuck and glue them, first together and next to the body of the core box. We next turn the body part of the core to a semicircle of the required size, and all that will then remain to be cut is that part of the branch that is above the line A B. If, however, the part below A B, in Fig. 127, should be required still longer, then it had better be built up in the same manner as the other part. The lengths of the pieces forming the courses will be the same, and may be measured on Fig. 127, from A B outwards. The widths will differ, and may be measured from E or F, inwards. This separate portion, from the grain of the wood being enduric, cannot be firmly fixed to the main body of the box with glue; we must, therefore, in addition, place battens below the box, and let in pieces of hard wood or metal above, as represented in Fig. 127, at G and H.

CHAPTER VII.

WHEEL AND PULLEY WORK.

Our fourth example is a double flanged pulley, shown in section in Fig. 128; and our first consideration is, how it shall be molded. It evidently should lie in the sand in the position shown in Fig. 129; but it will be observed that the sand is confined between two flanges, rendering it practically impossible to retract the pattern from the mold, if it is made in one piece. We say practically impossible, meaning that it cannot be done economically; for strictly speaking, an expert molder with every requisite appliance, can mold almost anything, as any one will conclude who examines the various works of art in bronze which appear in art exhibitions and elsewhere. Our pattern must, for ease of molding, be made in two parts. If the disk (or spokes, if it be a spoke-wheel) be sufficiently

Fig. 128.

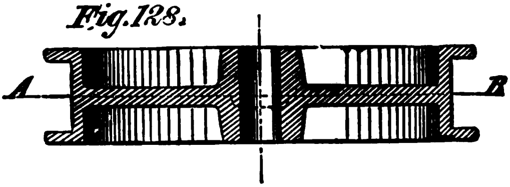
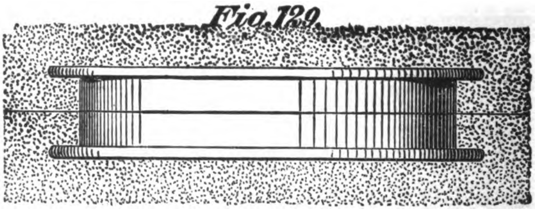
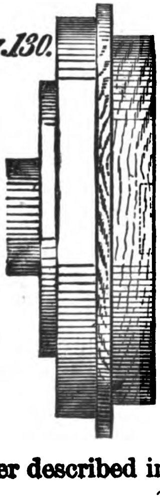


Fig. 129.



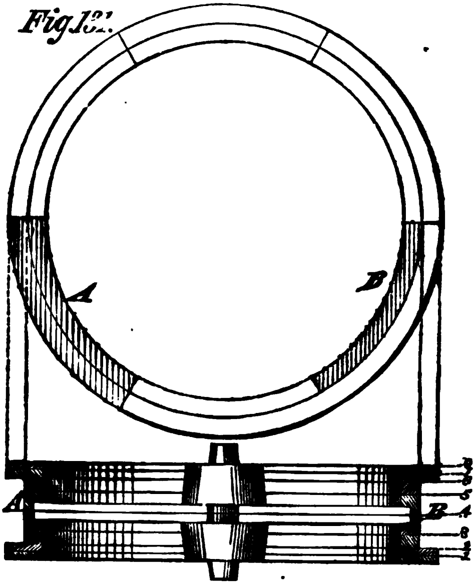
thick to allow it, the division may be made at the center, that is to say, on the line A P, in Fig. 128. The operation of the molder may be understood from Fig. 129, three distinct beds of sand being necessary. It may be that a part of a flask is used for each bed, or it may be arranged as shown in Fig. 129, it being a matter of indifference to the pattern maker. In either case, however, draught should be allowed both inside and outside, that is to say, both the interior and exterior diameters of the pattern should be made smallest at the line of parting, the diameters increasing slightly as they approach the flanges. The hubs also should, in like manner, be slightly tapered. Inside sharp corners should be avoided; they should, in fact, always be rounded by cutting them out with a round-nosed tool. To construct this pattern, we proceed as follows: For a small pattern, we take two pieces, somewhat thicker than half the thickness of the finished pattern, and large enough to allow for turning. We then chuck them, as shown in Fig. 130, and turn them up. The recesses, shown at the center by the dotted lines, must be made of equal size in the halves of the pattern; and we prepare a chuck with a projection across the center to fit into the recess, and thus rechuck the pieces, and turn out the opposite sides, cutting the hubs out of the solid. We may then fit a plug into the recess in one half of the pattern, and glue it fast, allowing it to project so as to fit into the recess in the other half; and the pattern is complete, unless the hole in the hub is to be cored, in which case it will be necessary to fix core prints on the top and bottom, in the manner described in our first example.

Fig. 130.



A useful hint may here be given to the effect that when it is decided to fix prints in the center of a piece of turned work, a slight recess may be made to receive the print, which is then sure to stand true; and should it at any time get accidentally knocked off, as prints often do, another may be immediately affixed without the trouble of finding the center. The pattern now supposed to be made, though good enough for many purposes, has one great defect which will be readily perceived when we bear in mind our remarks on the properties of timber. It is, that it will gradually become oval; and to avoid this, we must have recourse to what is termed building up, a process which must in any event be used, if the pattern is a large one. To build up such a pattern, we proceed as follows: After drawing the pulley in section and in plan, as shown in Fig. 131, we divide the whole height of the section into courses, the

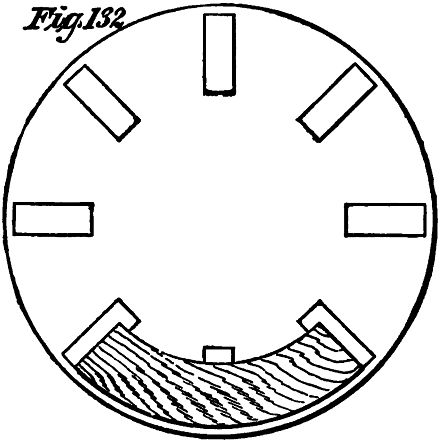
Fig. 131.



number of courses being regulated so as to have each of a convenient thickness. It is advisable, however, to have at least two courses in the flange, which will greatly increase its strength. After dividing one of the circles in the plan view into six parts, we draw lines from the points of division to the center, as shown; and then we make a template of one division, as shown at A, which must be made a little larger than the division, and this forms a template whereby to cut out the segments forming the courses which make up the flanges. A similar template, cut out somewhat larger than the space devoted to B, in Fig. 131, will serve to cut out the sections to be used in forming the body of the pattern. The flanges being made in two courses each, and there being six sections in each course, we shall require 26 pieces of the size of the large template; and allowing each half of the body likewise to consist of two courses, we shall require the same number, to form the body of the pattern, of the size of the small template.

Our templates being made, we plane up some pieces of board a trifle thicker than the courses are intended to be. It is easier to plane up the pieces of the board while yet square, than to plane up the segments separately. From the template, with a black lead pencil, we mark off on the planed pieces of board the requisite number of segments, and cut them out with a band or jig saw. We now proceed to building up, for which purpose we employ a chuck as a base whereon to build. It will save time, however, to have two chucks, building one half of the pattern on each, and both halves simultaneously, which will give sufficient time for each course to dry, without requiring nails or pegs to assist the glue in holding them together. The two chucks having been prepared, we glue to them strips of paper at intervals where the points of the segments will come, as shown in Fig. 132; and if the segments are very long, we glue another strip between each of these strips, so that the segment may lie level on the chuck. As the building proceeds, the end of each segment must be planed; and for this purpose, we require what is called a shooting board, which is a simple

Fig. 132.



contrivance, made in the following manner: We take a piece of board about 2 feet long, 8 or 9 inches wide, and nearly 1 inch thick, and also a piece of the same length, but 6 inches wide, and $\frac{5}{8}$ inch thick; and after planing them up straight, we screw one to the other, as shown in Fig. 133, at A B. S is a raised piece called a stop, and it should be recessed about $\frac{3}{8}$ inch into B, and dovetailed. It should not be glued, as the shooting board is useful for other purposes besides dressing segments: and it may be necessary to change the stop for one of a different height. In Fig. 133, the segment is shown in position for being dressed; while in Fig. 132 *a*, the truing plane is shown lying upon its side, in which position it works along the board, guided by the piece B.

The shooting board, made as above, when in use, lies upon the bench, butting against the bench stop, B G.

In cases, however, where the space is confined, the work bench being small, the shooting board may be worked lying across the bench, providing the stop, C, be affixed to it. The use of the shooting board, then, is to plane the end of each segment to its necessary length and angle; and having so dressed one segment, we glue it to the pieces of paper on the chuck, upon which a circle of the necessary diameter has been marked, as a guide whereby to set the first course of segments. We must not forget, while gluing the segment to the pieces of paper on the chuck, to give the ends of the segment a coat of glue for sizing, as explained in a previous example. Our next segment we treat in a precisely similar manner, save that, while gluing it to the chuck, we also glue it on the ends, so that it shall be sized at one end, and glued at the other to the segment already glued to the chuck, the object of the end gluing being to strengthen the building, and at the same time to prevent the corners of the segments from breaking out during the process of turning them in the lathe. As each segment is glued to its place, it should be clamped or weighted down, so as to expel the excess of glue, and also to prevent it from shifting while its neighbor is being butted against it.

Fig. 133.

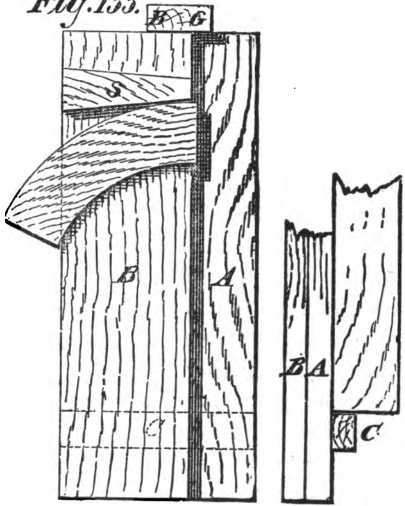
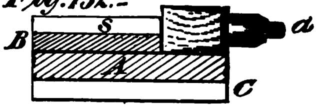


Fig. 132a



Having completed one course (which will, of course, be one of those intended for the flange), and allowed sufficient time for the glue to dry, we put the chuck in the lathe, and true up by facing off this layer of segments to its proper thickness, making the face straight, and testing the same by using a chalked straight-edge to make the high places more plainly visible. We then true the diameter of the course.

Our work is at present fastened to the chuck by the glue only; and for small work, only two or three courses high, this will suffice. But if the work is large, one screw should be inserted through the chuck into each segment, about half way between the points; and even then, if we build far out from the chuck, it will be necessary, after a few more courses have been added, to replace these screws by longer ones, which may be done (without disturbing the work) by replacing them one by one. If screws are inadmissible by reason of the danger of splitting the segments (as is sometimes the case), we must adopt another method; and that is, to discard the paper, and glue an extra course of segments firmly to the chuck, this extra course being afterwards turned away, until cut through.

The second and consecutive courses of segments are built up in the same manner as the first, the planed faces of the segments being glued to the respective faced courses on the chuck, until we arrive at the last course in the half pattern; and into this the half spokes or disc, whichever it may be, must be recessed, as shown in Fig. 131. The hubs are to be turned in the lathe separately, with a short plug on the under side, to fit a slight recess turned in the disk. If it is preferred, the disk or spokes may be made solid, and fixed to one half of the pattern, the other half and its half hub being left loose.

As we have stated that this may be a spoke wheel, it will be as well to explain the operation of making and fitting the spokes or arms. If the spokes are four in number, the process is very simple. We take two pieces of timber long enough to reach across the wheel, and plane them to the required thickness of arm, and have them sufficiently wide to shape the hollows about the hub and towards the rim. Then we make a mark with a pencil on one side of each, which we call the face. We then set a gage to half the thickness of the spoke, and with it mark lines on both edges of each piece, always gaging from the face side. We meet at the center of the length, cut a recess out of each sufficiently wide and deep to admit the other, so that the pieces, when put together, form a cross, which we let into the wheel and fix temporarily with brads. We now place the work in the lathe, and start the lathe so as to find the center of the wheel, from which center we draw out the arms, and then turn out the recess to receive the hub. We mark the arms to their respective places in the rim, so as to be able to correctly replace them, and then we take them out of the rim, and shape them to their proper conformation. This being done, we glue them to their places in the rim. In the case of six arms being required, all these operations are similar, with the exception that there are three pieces to be framed together for the spokes instead of two; and we proceed in the following manner: We divide the thickness of any one piece into three equal parts, and mark lines to these equal divisions on the edges of all the pieces. These gage lines need not extend the full length of the pieces, but only for some distance, about the center of the length, where it is expected the recess will be cut out. We next gage center lines on the flat sides, and find the centers of the length approximately. A, B, and C, in Fig. 134, represent our three pieces, which, when put together, are to form the six arms. Setting the compasses to a radius of one half the width of the pieces, we mark (from the centers already found) circles on one side of the pieces A and C, and also on both sides of B. We next set a bevel square to an angle of 60°; and with this, set to touch the edge of the circle, we draw, on A and C, tangents crossing each other; and on the piece B, four such tangents, two on each side, must be marked. The piece A must now be recessed between one pair of tangents to a depth of two thirds of its thickness, and between the other pair to a depth of one third. B must be recessed on each side to a depth of one third its thickness; while on the piece C, the whole of the space included between the tangents must be cut away to the depth of two thirds. The recesses must be cut true to the lines, and level, a rabbet plane being useful for the purpose, unless the work is small; and if the job has been carefully executed, the pieces will fit right together, and may be glued without further labor. For an odd number of arms, such as 3, 5, or 7, the method of putting together is different, and is not so strong as the

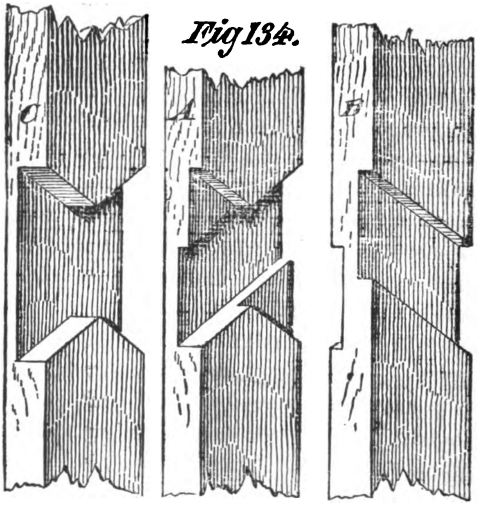
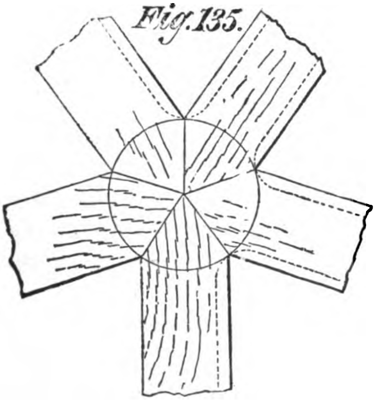


Fig 134.

foregoing. It is as follows: Upon a flat piece of board, fasten a piece of paper, and describe upon the latter a circle; then divide the circumference of the latter into as many equal parts as it is required to have arms, and draw lines from this center of the circle to the circumferential points of division, as shown in Fig. 135. Then bevel the ends of the pieces equally on each side, so that each shall exactly cover its own division of the circle; and as each is fitted, fasten it temporarily down, and when all are fitted, verify the work as follows: Observe if the pieces are equidistant from one another, at an equal distance from the center of the circle, and at or near the extremities, when any error will be easily detected and rectified. Then glue the pointed ends all together, fastening each piece temporarily to the board, as before, and set the whole away, until it is quite dry, when the piece may be taken from the board, and the required form given to the arms, ready for finally fixing to the rim of the pattern.

Fig. 135.



In almost all cases it is necessary that wheels of this kind be provided with hubs; and by the attachment of the latter, the joints of the spokes at the center, when made as shown in Fig. 135, are very much strengthened. But in the rare event of having to put together such a combination of arms without hubs, it will be advisable to turn out a recess at the center, making it as large as practicable, and fitting into it a disk of hard wood. Before cutting out the spaces in the rim to receive the extremities of the arms, it is necessary to turn out that part of the rim to the finished size, as it will be inaccessible to the turning tool, when the arms are glued in. The arms being fitted to their places, and made fast to the rim, we proceed to turn all that can be got at—that is to say, the exterior diameter of the body of the half of the half-pattern, and also the flange. It is needless to add that each half of the pattern must be similarly treated.

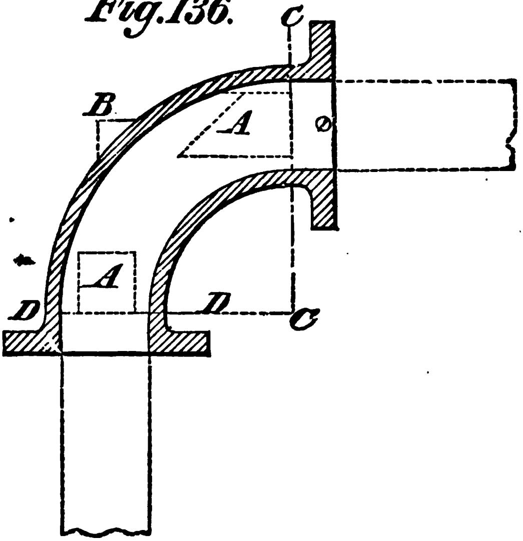
The work is now to be reversed on the chuck, and the inside turned out, together with a recess at the center, to receive the hub. To maintain the two halves of the pattern in coincidence, two, and sometimes three or more, pegs are inserted in the arms of one half, which pegs fit into holes bored to correspond in the arms of the other half of the pattern. In some cases, the flanges of the pattern are required to be so thin as not to admit of two layers or courses of segments in their composition, in which event—especially if the flanges extend far from the body of the pattern—it is well to strengthen the joints of the segments. Perhaps the neatest way of accomplishing this, is to make a saw cut in the ends of each segment, and, at the time of gluing, to insert a tongue or thin strip of wood, nicely filling the saw cut, the grain of the tongue being at right angles to the line of the joint of the segments. Care should, however, be taken to have the saw cut in each at a similar distance from the face of the segment. It will be perceived that the flanges might be omitted without making any difference in the method of construction; nor does the method to be pursued vary to any great extent for all kinds of rope or chain pulleys.

CHAPTER VIII.

PIPE BENDS, AND LAGGING.

Our next example will be a pipe bend, such as is shown in section in Fig. 136. It will be seen upon examination that the bend proper is included in that portion contained within the dotted lines, C C and D D, which meet at the center from which the arcs, forming the bend, are struck. Those parts exterior to the dotted lines are made separately from the bend proper, and are subjects in plain turning, similar to those already treated upon. It will be noted, however, that in this kind of pattern the core is not so well supported as in our previous examples; and it has, there-

Fig. 136.



fore, a tendency to sag or droop towards the center of the arc, and also to rise above its proper level when the metal is poured into the mold. To obviate this, we must make the core, and hence the core prints, extra long, as shown by the dotted lines in Fig. 136. It is usual also to make a provision for fastening these external pieces to the bend proper, as follows: The flange is one piece, the bend proper another, and the core print yet another. The core print fits into the flange, and has a projecting piece extending into a recess or hole, provided in the bend proper to receive it, as shown, and thus is the pattern strengthened. If the core prints are made so short that the core overbalances itself when placed in the mold, the molder inserts into the mold, stays or supports to keep the print in position; and these supports are called chaplets. They consist of pieces of thin sheet iron, bent to about the curvature of the core, and riveted to a piece of wire, the device being pressed like a flat-headed nail into the sand. The piece of sheet iron represents the nail head upon which the core rests, and it is inserted into the cope and nowel, so that they project the proper distance. They act to prevent the core from either sagging or lifting, by floating upon the molten metal. Then, when the casting is taken from the mold, the projecting wires are chipped off, and that remaining in the casting is riveted. This trouble can be, in many cases, saved, by simply making the core prints a few inches longer; besides, wherever there is a chaplet, there is an excrescence left upon the casting. In the case of large work, however, the matter is different, on account of the expense of making very long prints, and their awkwardness in being handled.

The bend part of our pattern may be either turned in the lathe or pared by hand; and sometimes it is a difficult matter to decide which of the two will best answer the purpose. To turn up a bend, it is necessary to turn up a ring semicircular in section, as shown in Fig. 137, and of a radius corresponding to that of the required bend. This ring is then cut up into portions of the length of arc required, and about one half is in most cases left over. The advantage of this method is the direct and ready manner in which the required form is obtained; whereas, in paring and shaping, the bending by hand, though the operation be ever so skillfully performed, will not be so true as if turned. And when we consider that castings only three thirty-seconds of an inch in thickness are sometimes required, we perceive that the slightest error or deviation from the true shape will be perceptible, and will often result in the loss of a large proportion of the castings. For all small work, then, the turning is of decided advantage; but since such is not always the case with large work, and since the line must be drawn somewhere, a correct decision will always be largely influenced by the facilities afforded by the tools, etc., in the shop. In the example shown in Fig. 138, which is what is called a return bend, the whole of a ring, turned as above described, would be appropri-

Fig. 137.

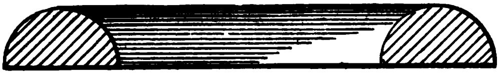
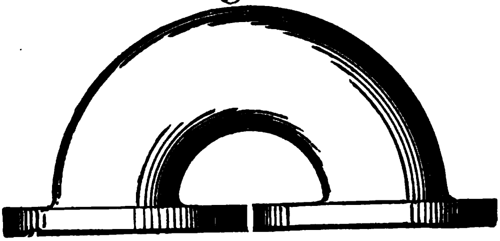


Fig. 138.



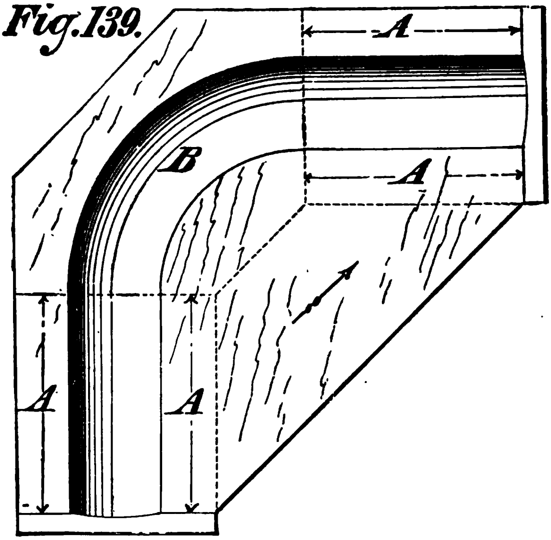
ated: therefore, there being no loss of material, the method by turning will in this instance always be preferable.

In fixing the half flanges for work of this kind, not exceeding six or seven inches in size, one screw passing through the center of the pattern into the flange will be sufficient. Care must, however, be taken to hold the flange firmly in its exact position, while boring for and during the insertion of the screw. It should not be forgotten to add the small projecting piece, B, shown in Fig. 136, which lies in the center line of each arm of the bend, which is provided to enable the casting to be conveniently swung in the lathe.

Before quitting examples of this kind, it will be well to once more direct the reader's attention to the core boxes, so as to impress upon him the important fact that, where equal thickness of metal is required, the core box should be as the pattern is. A round pattern demands a round core box; the one is of equal importance with the other. For example, in the designing of a bend, the required thickness is determined by the amount of internal strain to which the casting will be subjected. If, then, we give a round bend and an oval core box, we either make the bend too weak, or we cause the manufacturer to pay for so many pounds of metal which he does not require. In the case of castings so thin as to require care to make the metal flow throughout the mold, an unduly thin place or spot will prevent the flow (at that part) of the metal, and thus spoil a large proportion of the castings.

A half core box for either a bend or a T may be made by preparing a block sufficiently large to cut out the whole recess, as shown by the full lines in Fig. 139. In this case, after the block has been surfaced truly on one side and edge—the grain of the wood being in the direction denoted by the arrow—the center lines are marked upon it, and also upon the pattern. We then lay one half of the pattern upon the block, and make the center lines upon them come exactly fair and even; and then we mark upon the face of the block the outline of the pattern, core prints and all. The core prints will, of course, be the right size of the core; but the outline marks thus produced form a guide to work by, and the distance between these outline marks and the edge of the core will represent the thickness of metal in the finished casting. A margin of stuff in the block is

Fig. 139.

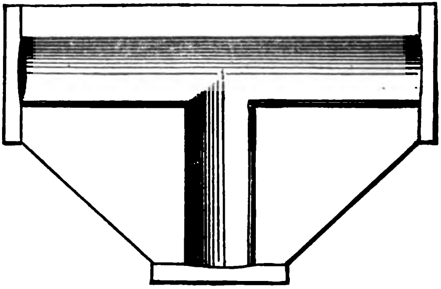


required outside of the outline marks, so as to give the core box sufficient strength. We next trace out a plan of the core, and then, upon the ends or sides of the block, we describe semicircles representing the exits of the recess to be cut out, the block being left so deep as to leave stuff enough below the depth of the recess to afford ample strength. We may now proceed to cut out the core by our hand tools, finishing it with the plane shown in Fig. 14, and smoothing it with sand-paper wrapped around a piece of wood of a sweep or curve a little less in radius than that of the core box recess.

Another method of getting out a core box for a bend is shown by the dotted lines in Fig. 139; and in this instance we make the core box in three pieces—the object being to turn up the end pieces, A A, in the lathe—the manner of procedure being as follows: We get out the two pieces marked A A, and square up the faces truly, and chuck them, with the planed faces placed together in the chuck shown in Figs. 56 and 57, taking care that they are chucked so that, when the hole is bored in them, it will be half in each piece, or, in other words, chucking them truly, with the joint between the two. We then pare out the curved part in the middle section, and then glue on the end pieces, A A, A A, and strengthen the whole by placing battens on the bottom and sides.

Fig. 140 represents a half core box for T. In half core boxes it is necessary to close the openings in the ends or sides by bradding on pieces of light board, taking care to give draught by paring them slightly concave at the top, and thus making the ends of the core similar to the slightly rounded ends of the pattern. When these pieces are

Fig. 140.



omitted, the core maker has to extemporize them. When a full core box is required, as in the case of the oblique T, it is sufficient to mark the shape of the core upon one half only of the box; and when this is cut out, we may place the two half boxes together, and trace the second half from the finished one, using a large bent scriber for the purpose of marking.

Economy in timber and in the cutting must be studied as much in the core box as in the pattern; hence, when the pattern is of such a size as to render it economical to build it in pieces, it will be equally desirable to build the core box in like manner. For the bend itself, however, it is scarcely necessary to speak, for the core can be made with a simple contrivance; whereas the building of a half box, though not offering any elements of difficulty, demands so much labor in the cutting out, compared with the extra labor devolving upon the core maker employing the contrivance referred to, that such boxes are for large work seldom or ever constructed. We proceed, therefore, to describe the contrivance with which the core maker is usually supplied. It is applicable to all sizes where loam cores are used; but the core box is preferable when its construction involves no great outlay.

Having determined upon the size of the core from end to end of the prints, we proceed to make a pattern from which one or two iron plates may be cast. Upon these plates the core, in separate halves, is made and dried. The plates are generally about $\frac{5}{8}$ inch thick, and of such a width as to leave a small margin around the core, to support what is called the strike. In Fig. 141, P represents the plate, C the core, and S the strike; this latter is cut from a piece of board from $\frac{3}{8}$ to 1 inch thick, the semicircular hole cut in it being the size of the required core. The grain of the wood may run in the direction of the arrow. It is strengthened, if necessary, by the two battens, shown in Fig. 141 *a*, at B B. The edges of the semicircle are beveled off, which causes the strike to work more smoothly and correctly over the composition forming the core.

A few flat-headed tacks should be driven into the surfaces of the strike that come into contact with the iron plate, so as to prevent the wood from wearing rapidly away, and thus altering the shape of the core, and causing it to be oval. The core maker places upon the iron plate enough material to make the core, and, taking the strike, places it so that the edge or shoulder, A, in Fig. 141 *a*, contacts with the edge of the plate. He then sweeps the strike over the material; the semicircle leaves the core upon the plate, and sweeps off the surplus material, the sweeping process being completed until the perfect half core is formed. In Fig. 141 *a*, P represents the plate, S the sweep, and C the material or core, the figure being an end view, and the tacks referred to being shown, so as to mark their location.

Fig. 141

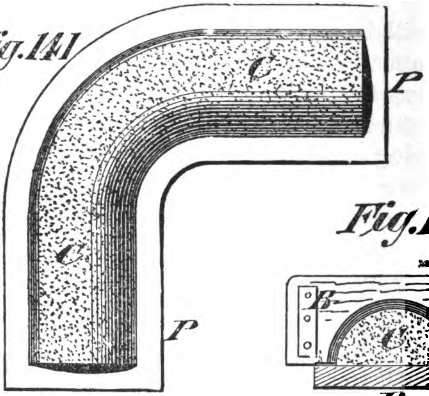
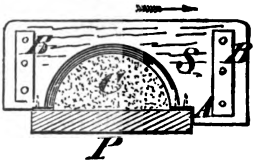
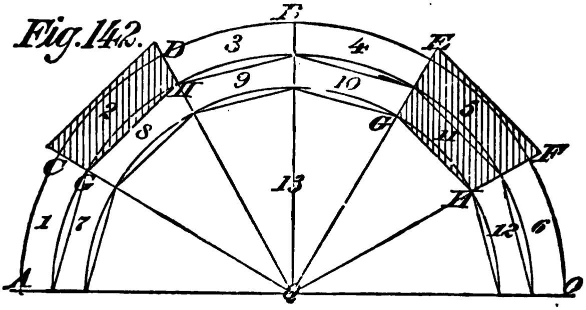


Fig. 141 a



We have hitherto treated of building patterns of such size that they could be made out of the solid; it often happens, however, that the pattern maker is required to build up a pattern by what is called staving or lagging. As an example of this kind of work, let it be required to stave up a pipe, 18 inches diameter inside, with 1 inch thickness of metal. We proceed by taking a clean board, and drawing on it the line, A O, in Fig. 142; and then we describe upon it the semicircle, A B O (for we will suppose the pattern to be made in halves), of the required finished size of the pattern, the shrinkage being allowed for. This semicircle we divide off into as many equal parts as it is intended to have staves; and we next draw radii from the points of division to the center of the semicircle. We then

Fig. 142.



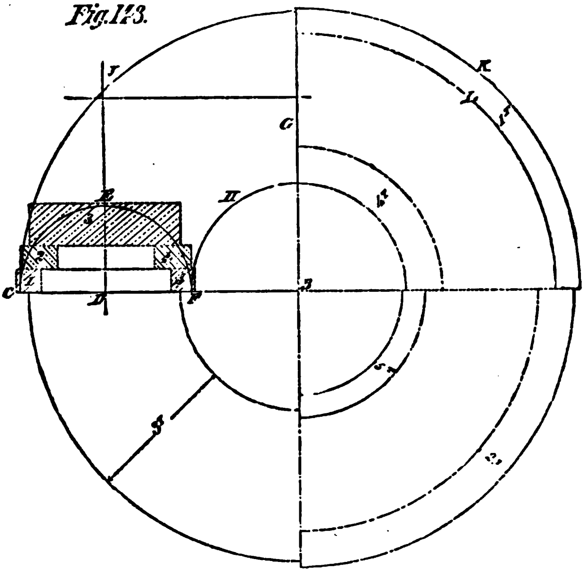
take any one of these divisions — of which there are six shown in Fig. 142 — and draw the line, E F, parallel to an imaginary line joining the points of division, C D. The distance of the line, E F, from the arc is the amount allowed for the lathe turning — say in this case, $\frac{1}{8}$ inch. We next draw the line, G H, parallel to E F, and the figure, E F G H, is the exact size and form required for each stave. From the center, Q, we then describe a semicircle passing through the points, G H, and cutting each of the radii; and by joining all these points, we form the half polygon, shown by the whole figure. This shows the exact size and shape of the disk to which the staves are to be fixed. In Fig. 142, this whole process is drawn twice, showing thick staves and thin ones; from 1 to 6 representing the thick, and from 7 to 12 the thin staves, while 13 represents the disk of wood. The thin staves are to form the body of the pipe; but when it is desired to have the points solid with the body, we must use the thick staves. The first procedure is to prepare the requisite number of disks, making them of the form shown; and some pattern makers do this by turning the disks, and then flattening them off to form the sides of the polygon. But when a band saw is accessible, the turning is unnecessary; and we may simply draw them out and saw almost to the line, allowing say $\frac{1}{16}$ inch for finishing. Each half disk should be pegged to its mate, and a template, like the figure E F G H, is useful in preparing the staves and verifying their sizes. To prepare the staves, we cut out with the rip saw the required number of pieces, a little wider than E F, in Fig. 142; or if there is a circular saw at hand, we use it in preference, and it will save time to resaw the pieces, to give them the required bevel, which may be done by canting the saw table. In the absence of any provision for canting, we may fix a packing piece to the table, so as to elevate one edge of the stave. After sawing, we plane the bevel edges to correspond to the template, leaving just a shade of stuff to allow for jointing the staves at a close fit together.

Having prepared the staves, we set up the pattern, as follows: On a planed board, the requisite number of half disks are placed, perfectly in line with each other; and the outer ones must be at such a distance apart as to allow for turning up the ends of the staves. The intermediate disks, if any (and they should occur about every 2 or 2½ feet), are to be distributed at equal distances in the space that intervenes. These disks we then fix temporarily to the board, paper being laid at the ends of the disks to catch the surplus glue.

The staves are glued, and each screwed with one screw to the disk. The boring of the stave to receive the screw should be performed before applying the glue, and the head of the screw should be well sunk beneath the surface, so as to admit of a wood plug being glued in on top of it. First, a hole is bored in the stave, a little larger in size than the head of the screw, and nearly as deep as the screw head is to be sunk; for, in tightening the screw, the head will be sure to be driven $\frac{1}{8}$ or $\frac{1}{4}$ inch deeper than the hole is bored—that is, providing the material is a soft wood, as is usually the case. The stave is now to be completely pierced with a hole just fitting the plain part of the screw. If it is larger, the head of the screw will sink deeper; while, if it is smaller, a thread will be cut in it by the screw, and it may prevent the stave from being drawn to its place. The glue should be applied and the screw inserted while the glue is hot. It is best to join on a stave back and front; that is, at each end first, and to then put in the middle or connecting stave, thus completing one length of the staves, the top one being, preferably, the first erected. In putting on the succeeding staves, each one should be properly jointed to its fixed neighbor; a little chalk being rubbed on the fixed stave will show if its fellow bears or joints properly. When one half of the pattern is finished, we may dispense with the board, using the finished half in its stead, and taking care to insert paper between the two, to prevent the glue from sticking them together.

In lagging up a branch for a T, the disk at one end should be set back sufficiently far to allow for the part to be cut away in fitting the branch to the body of the T, as explained when treating that subject. This method of staving is that regularly employed for cylinders, pipes, rollers, and similar jobs; and though sufficiently simple for straight pieces, it becomes very complicated when applied to a bend. It is not, therefore, usual to stave up a bend, but to build it in the manner illustrated in Fig. 143.

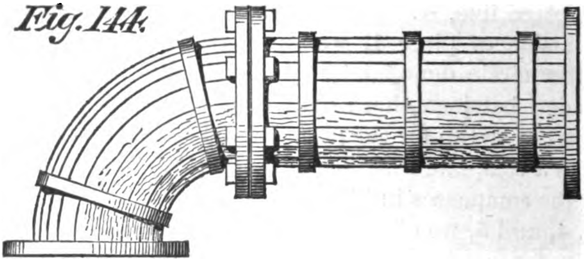
Fig. 143.



The operation is, to first draw the bend in plan, of the full size, upon a board. Let B, in Fig. 143, represent the center from which it is struck, the plan in this case being a quarter circle bend, denoted in Fig. 143 by the line C D F, the line G, and the sections of a circle, H and J. We have decided to build up our pattern with five pieces, an end view of the half pattern being denoted by the circle C E F, and five pieces or layers being denoted by dotted lines, so that by adopting this method we show the plan and end view of the bend in one drawing. It would be well now to cut out forms, in card or in very thin wood, as templates, one for each of the pieces, marked from 1 to 5 respectively. To obtain these templates, we draw the line C B; and from the center, D, we describe the semicircle C E F, representing the diameter of the half bend. We then lay off the tires from 1 to 3, as shown by the dotted lines; and to find the bends necessary for each respective piece, we proceed as follows: Setting our compasses at a distance equal to that between the center from which our bend is struck (B in Fig. 143) and the extreme outside of the piece marked 1, we draw the quarter circle denoted by the dotted line, K. Then setting our compasses from D to the inside of piece 1, we draw from the center, D, the quarter circle denoted by the dotted line, L. The space included between those quarter circles, and denoted by I T, is the sweep for the piece 1; and we may cut it out for use as a template wherefrom to mark out piece 1. By setting the compasses in like manner for each respective piece, 2, 3, 4, and 5, we obtain the templates, 2 T to 5 T, respectively, for use in marking out the pieces upon the board from which they are to be sawn. In building the pieces up, we lay those forming the lower tier on the plan previously drawn out on the piece of board, putting them a little outside the lines, to allow for finishing. We then temporarily fix them in that position — the faces being, of course, planed up. We now glue on the next tier. It is well, however, to have a semicircle made of a piece of thin wood, and of the size of that shown in Fig. 143, by C E F, which we may place upright against the ends of the first tier, as a guide in adjusting the position of the second and succeeding tiers. The number of tires is discretionary; but it is well to have the top piece comparatively thick, so that it shall not be liable to curl, as it would be apt to do, if the turning left it thin. If the joints of the tiers are well surfaced and well glued, neither nails nor screws will be needed. It is not compulsory to make each layer a continuous piece, and it will save stuff to make every alternate layer of two pieces; but the bottom and the top layers are better, if each be made in one piece.

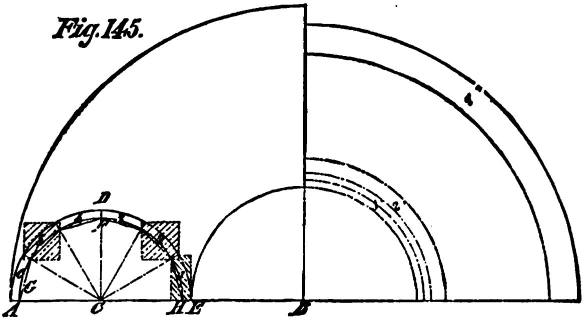
It will be observed that this staving up a bend is both laborious and wasteful; yet there are cases in which it becomes imperatively necessary to make it in this manner. A very common job of this kind is lagging up a steam pipe, such as shown in Fig. 144. The pipe is usually covered with felt or some other non-conducting material, and covered round with mahogany or walnut. Now, it would be very unsightly to have the joints in the bend out of line with those on the straight part of the pipes. A hollow bend of wood has, therefore, to be constructed, having in it the same number of staves as there are for the straight pipe. To get out the pieces for such a bend, we proceed as illustrated in Fig. 145, in which there are shown 6 sections or staves, the semicircle G H representing the required inside diameter of the bend; while the semicircle A E represents the required outer diameter. We then divide off one of the semicircles into the required number of divisions; and we draw radii, and then form rectangles around each division or space representing a stave, as shown by dotted lines in Fig. 145 at 2, 3, and 5. The method pursued in getting out these staves is precisely similar to that pursued in building up in our

Fig. 144.



last example. In this case, however, as each stave is fitted to its fellow, it should be held to its place by dowels—that is, small pins of wire placed at frequent intervals—which will serve instead of glue, which would not answer, by reason of the heat from the steam pipe. The disks upon which the bend is built, and of which there should be at least three, are merely temporary; and therefore the staves are not to be fastened to them, except for convenience, so as to keep them in position. For this purpose, a piece of paper, with a little hot glue on each side, should be placed between the stave and the disk; it will make a fastening sufficiently strong, if a little pressure be applied during the drying. Neither nails, screws, nor staples, are admissible on this kind of job, as they would mar the appearance of the work when finished and polished. The two halves of the bend being completed, they are made to go together with loose pegs—that is to say, pegs that do not fit the holes tightly, as the dowels do. The halves should be held together by polished brass or plated bands; and the neatness of the finished appearance will amply repay the cost and the trouble, for the polished wood forms a pleasing contrast to the contents of an engine room, where almost everything the eye can rest on is iron.

Fig. 145.

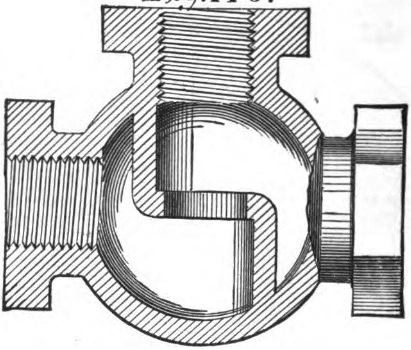


CHAPTER IX.

EXAMPLES IN GLOBE VALVES.

In Fig. 146, we have for an example a common globe valve, shown partly in section and with a gas thread cut in the openings. The flanges vary in shape; but, as a rule, small valves are provided with hexagons, and large ones with round flanges suitable for bolting to similar flanges to make joints. For small valves, say up to 2 inches, the pattern is usually made with the hexagons cut out of the solid, but for sizes above that, they should be made in separate pieces, as shown in Fig. 147, and screwed to the pattern, so that in case of necessity they may be removed, and flanges substituted in their stead. In Fig. 148 we have a perspective view of the finished pattern; and Fig. 149 represents the pattern as prepared, ready to receive a flange or hexagon as may be required. A globe valve pattern should be made in

Fig. 146.



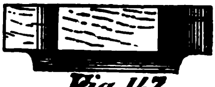
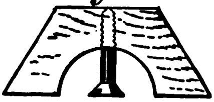
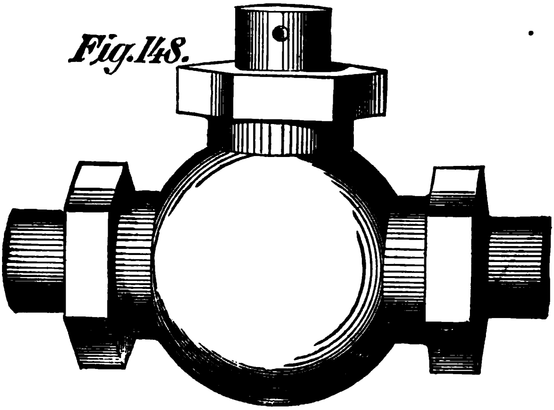


Fig. 147.



halves, as shown in Fig. 150, the parting line of the two halves being denoted by A B. To make this pattern, we first prepare two pieces of wood so large that, when

Fig. 148.



pegged together, the ball or body of the pattern can be turned out of them, and long enough not only to reach from P to P, in Fig. 149, but also to allow an excess by means of which the two pieces may be glued or otherwise fixed together. These two pieces we plane to an equal thickness, and then peg them to retain them in a fixed position, taking care, however, that the pegs do not occur where the screws to hold the flanges will require to be. We also place two pegs within a short distance of what will be the ends of the pattern when the excess in length referred to is turned off. We next prepare, in the same way, two more pieces, to form the two halves of the branch, shown at B, in Fig. 150, for which, however, one peg only will be necessary. These pieces must be somewhat wider than the size of the required hexagon across the corners—that is, supposing the hexagon is to be solid with the branch—otherwise we must make them a little wider than the diameter of the hub of the flange or of the round part of the hexagonal pieces. Their lengths must be such as to afford a good portion to be let into the ball or body of the pattern (as shown by the dotted lines in Fig. 149), which is necessary to give sufficient strength. The two pieces must be firmly fixed together, and then turned in the lathe.

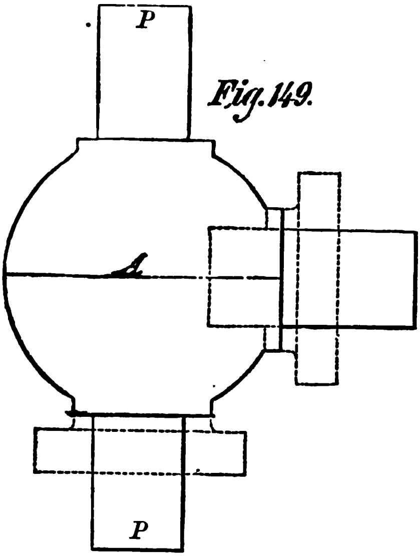


Fig. 149.

During the early stages of the turning, or, in other words, during the roughing out, we must occasionally stop the lathe and examine the flat places on the body; for unless these places disappear evenly, the work is not true, and one half will be thicker than the other, so that the joint of the pattern will not be in the middle. It was to insure this, that the pieces were directed to be planed of equal thickness, since, if such is the case, and the flat sides disappear equally and simultaneously during the turning, the joint or parting of the pattern is sure to be central. If the lathe centers are not exactly true in the joint of the two pieces, they may be made so by tapping the work on the side having the

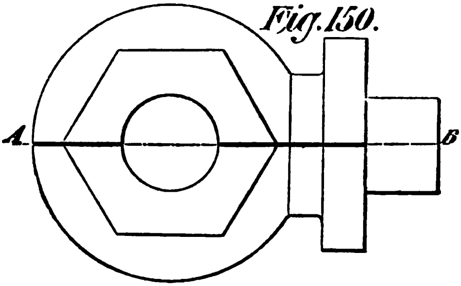


Fig. 150.

narrowest flat place, the process being continued, and the work being trued with the turning tool at each trial, until the flat places become equal. By this means we insure, without much trouble, two exact halves in the pattern, which is very important in a globe valve pattern, on account of the branches and other parts, not to mention the molding. Having turned the body of the pattern to the requisite outline, and made while in the lathe a fine line around the center of the ball where the center of the branch is to come, as shown in Fig. 149, by the line A, we make a prick point (with a scriber) at each crossing of the line A and the joint or parting of the pattern. We then mount the body upon a lathe chuck, in the manner shown in Fig 151. A point center should be placed in the lathe, and should come exactly even with the line A. In Fig. 151, V V are two V blocks made to receive the core prints. These V's are screwed to the lathe chuck, and the pattern is held to them by two thin straps of iron placed over the core prints and fastened to the V's by screws. If the chuck and center point run true, the V blocks are of equal height, and the core prints are equal in diameter, the prick point opposite to the one placed to the center point will run quite true; and we may face off the ball or body to the required dia-

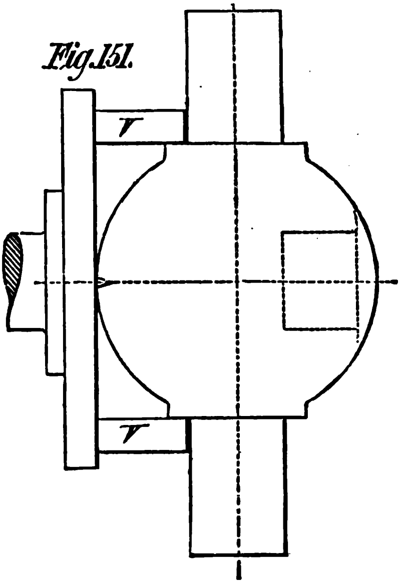
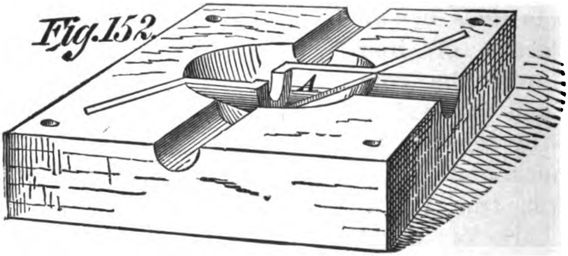


Fig. 151.

meter of branch, and bore the recess to receive the same. We make the holes in the flanges of the same size as the core prints; but we should not check in the print, because, if a flange with a different length of hub were substituted, it would be a disadvantage. To obtain the half flanges, we take a chuck and face it off true in the lathe; then, with a fine scriber point, we mark the center while the chuck is revolving. We then stop the lathe, and placing a straight-edge to intersect the chuck center, we draw a straight line across the chuck face. We then take two pieces suitable for the half flanges, and plane up one flat side and one edge of each piece. If the flanges are not large ones, they may be planed all at once in a long strip. We place the pieces in pairs, and mark on each pair a circle a little larger than the required finished size of flange. We then fix each pair to the chuck, with the planed faces against the chuck, and the planed edges placed in contact, their joint coming exactly even with the straight line marked on the chuck face, and we may then turn them as though they were made in one piece and to the requisite size.

In Fig. 152, we have a representation of one half of a suitable core box, the other half being exactly the same, with the exception that the position of the internal partition is reversed. To get out this core box, we plane up

Fig. 152.



two pieces of exactly the same size and length as the pattern, and of such width and thickness as will give sufficient strength around the sphere, allowing space for the third opening. After pegging these two pieces together, we gage, on the joint face of each, lines representing the centers of the openings and the center of the sphere. We then chuck them (separately) in the lathe, and turn out the half sphere. We next place the two halves together, and chuck the block so formed in the three positions necessary to bore out the openings; or, if preferred, we may pare them out. The partition (A, in Fig. 152) follows the roundness of the center hole, and is on that account more difficult to extract from the core, than if it were straight and vertical. When, however, the partitions are of this curved form, the pieces of which they are formed are composed of metal, brass being generally preferred. Patterns have in this case to be made, wherefrom to cast these pieces, and they may be made as follows: First, two half pieces, such as shown in Fig. 153, are turned; each is then cut away so as to leave the shape as shown at C, in the same figure, and is then fitted into the spherical recess in the core box, letting each down until both are nearly but not quite level. The two pieces, A and B, in Fig. 153, are then fastened on, and this pattern is complete. When the pieces are cast, they must be filed to fit the core box, and finished off level with its joint face, a small hole being drilled in the center, and a pin being driven through the piece and into the box, to steady the

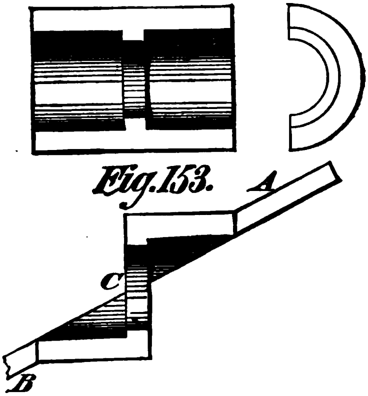
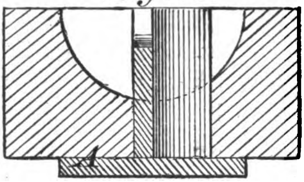


Fig. 153.

corners. We then saw the pieces in halves with a very fine saw.

If the partition, instead of following the roundness of the valve seat, is made straight, the construction of the core box is much more simple. In this case, a zigzag mortise is made clear through each half of the box, its size and shape being that of the required partition. Fig. 154 represents a half core box of this kind. A piece of wood, A, is fixed as shown to the partition, to enable the core maker to draw it out before removing the core from the box. The mortise for the partition should be turned out before the half spherical recess—the mortise being temporarily plugged with wood, to render easy the operation of turning.

Fig. 154.



In very large valves (say 10 or 12 inches) a half core box is generally made to serve, by fitting the two half partitions, shown at C, in Fig. 153, to a half core box, and keeping them in position by means of pegs; a half core being made first with one, and then one with the other in the core box. It is often necessary to form a raised seat in the body of an angle valve, such as shown in Fig. 155, which represents a section of such a body. It is shown with flanged openings, though in small valves hexagons, to receive a wrench, would be substituted.

Fig. 155.

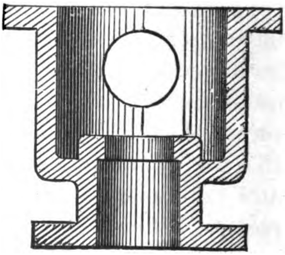


Fig. 156 is a plan of half the core box necessary for forming the raised seat. From this construction it will be seen that the large core, though solid with the branch core, is not solid with that forming the hole in the seat and the part below it; therefore the core prints on the body pattern must be left extra long, to give sufficient support in the mold for the overhanging cores. The loose round plug, P, is made of the size of the outside of the seat, and fitted to the box. The part outside the box is a roughly shaped handle to draw it out by. The diminished part, D, is a print, and into the impression left by it is inserted the core made in box, shown in Fig. 157. The print, D, is of the same diameter as the hole in the seat; and the print on the pattern is of the size of the increased diameter below the seat. Large angle valves are made with half a core box, by making a branch opening in the box right and left, a semicircular plug being provided. Two half cores are made with the plug, first in one and then in the other branch opening. The plug, P, should be in this case only half round.

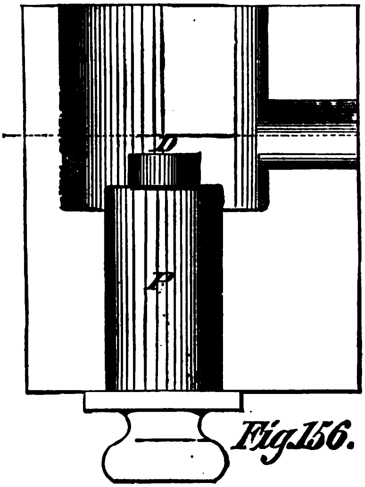


Fig. 156.

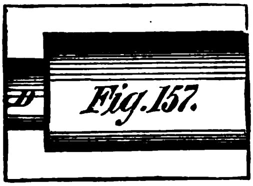


Fig. 157.

CHAPTER X.

JOINTS, AND EXAMPLES IN BENCH WORK.

Turning now for a space from examples requiring so much lathe work, we come to deal more particularly with the bench, and the devices and operations connected with it.

A good bench is a great assistance to a pattern maker. It should be perfectly true on its upper surface, which is best made of hard wood, and covered with a coat of varnish to prevent dust or drippings of glue from adhering to it, so that it is always cleanly in appearance. The vise, when screwed close to the bench, should come level with its top, and the butt or stop for work to press against, should be so constructed that its height may be readily altered, as this will have to be done perhaps fifty times a day. In the absence of a well contrived mechanical stop, which always admits of re-adjustment without stooping, I should recommend a stop of wood made by placing two wedges together, as shown at A and B, Fig. 158. A pin is fixed tightly in the wedge A, which slides in a groove, in B, for a short distance; this prevents the wedges from falling apart when loosened. A light tap on B loosens, and one on A tightens the stop. The ordinary contrivances used at the bench, in addition to the workman's tools, are the shooting board (already described), the mitre box, and the bench hook. The mitre box is a contrivance to enable a workman to saw moldings, pipe patterns, etc., to an angle of 45°. It is simply a trough

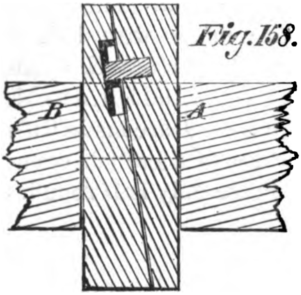


Fig. 158.

with saw cuts made at the required angle. The stuff to be cut is laid in the trough and pressed to one of its sides, the saw being guided by the saw cut. The bench hook is a piece of wood sawn to the shape shown in Fig. 159,

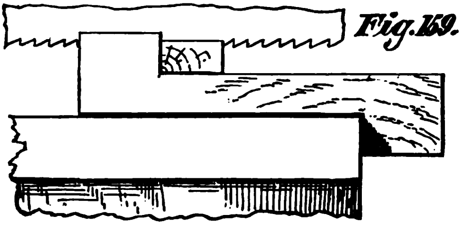
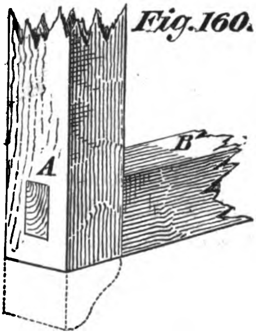


Fig. 159.

and is used as a butt; for timber, in cross-cutting work, should not be sawn directly on the bench.

Fig. 160.



Figs. 160, 161, and 162, are illustrations of different methods of jointing pieces of wood together so as to form a square or any angle. Fig. 160 represents a tenon and mortise joint, made as follows: The two pieces, A and B, having been planed or otherwise made to size as required, are marked for the position and length of the mortise in one case, and for the length of the tenon in the other; both pieces are now gaged with a mortise gage, both being marked alike; and then from the face side we mark a tenon or mortise of the size required, which is generally a third of the thickness of the stuff. Where the mortise approaches the end of the piece, a provision has to be made to insure strength, by adding the extension denoted in Fig. 160 by the dotted lines. This practice, however, though often adopted in carpentry, is rarely admissible in pattern work; and in its stead, the tenon, or the piece B, is diminished in width, as shown in Fig. 163, the mortise being made to correspond. In order to avoid breakage during the cutting of the mortise, the piece A, Fig. 160, is got out an inch or two longer, which excess is sawn off after the glue is dry. An excess of ¼ to ½ an inch should also be allowed on the tenon, as it is necessary to chamfer off the corners of the tenon, so that in driving it may not damage the mortise. To prevent the tenon from, in time, working out, the mortise is slightly tapered—that is, made wider on the side remote from the piece carrying the tenon. Then the tenon is provided with two saw cuts, one on each side, near the edge; and after being driven home, wedges are driven into these cuts, thus locking the joint. A joint, more commonly in use among pattern makers, is the half lap, shown in Fig. 161, which has been already described. When this joint occurs away from the end of the pieces, the mortise need not, and should not, extend through the piece. This joint, besides being glued, may be fastened with screws, or if very thin, riveted with short pieces of lead wire.

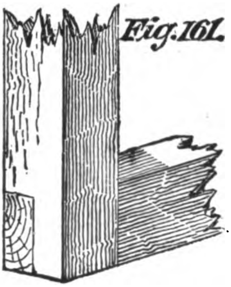


Fig. 161.

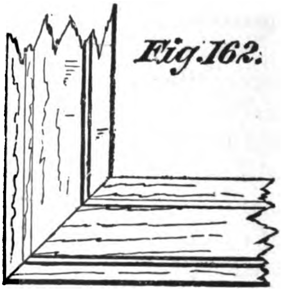
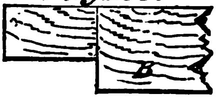


Fig. 162.

Fig. 163.


A very superior method of jointing is the dovetail, shown in Fig. 164, which is serviceable for connecting the ends and sides of a box, or any article in that form. The strength of the corner formed in this way is only limited by that of the material itself; therefore, it should be preferred, when available, in making standard patterns, or for work too thin to admit nails or screws. The corner formed by this joint is not limited to 90° or square, so called, but may form any angle. Nor is it imperative that the sides or ends of the box or other article be parallel. They may incline towards one another like a pyramid; a mill hopper is a familiar example of this. If it be required to dovetail a box together, get out four pieces for the sides and ends, to be of the full length and width of the box outside, respectively. They are to be planed all over, not omitting the ends. The gage, that is already set to the thickness of the stuff, must now be run along the ends, marking a line on both sides of each piece. Then mark and cut out the pins as on the piece A; the dovetail openings, in B, are traced from the pins in A. The pieces, having been tried and found to go together, are finally brought into contact and held in their places with glue.

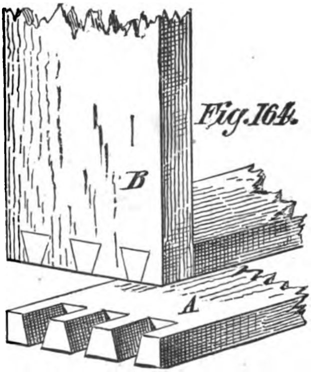
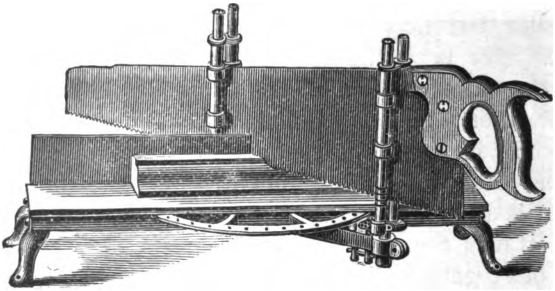


Fig. 164.

Fig. 162 is a mitre joint—the only one serviceable to moldings, pipes, and other curved pieces. It is not a strong form of joint, and is only used where the preceding kinds are inapplicable. It is made with glue, the pieces having been previously sized; and as an additional precaution, if the work will admit, nails, brads, or screws, are inserted at right angles to one another.

In Fig. H is shown a mitre box exceedingly useful as a shop fixture, but of course, being made of iron, it is not intended to form a part of a journeyman pattern maker's kit of tools, but rather from its superiority to dispense with the necessity for the same. The saw blade is guided by the rolls shown upon the upright spindles, and leaden rolls below regulate the depth to which the saw will cut, and thus preserve the saw teeth from contact with the iron frame.

Fig. II



This mitre box can be used with a back saw or a panel saw equally well. If a back saw is used, both links which connect the rollers, or guides, are left in the upper grooves, and the back of the saw is passed through under the links. If a panel saw is used, the link which connects the rollers on the back spindle is changed to the lower groove; and then the blade of the saw will be stiffly supported by both sets of rollers, and be made to serve as well as a back saw.

As an example, to make the pattern for a pillow block, as shown in Fig. 165. This pattern will be more easily molded with the base up; that is to say, it will lie in the sand in the reverse position to what it is drawn in Fig. 165. Prints will be required for the bolt holes, square prints for the recesses in the block intended to be cored out to receive the heads of the cap bolts, round prints on the tops of the cheeks, and oval prints on the base. We first plane a piece for the base, B B, to the correct size, allowing $\frac{1}{10}$ inch to the foot for the contraction of the casting in cooling. We next draw center lines upon it on both sides.

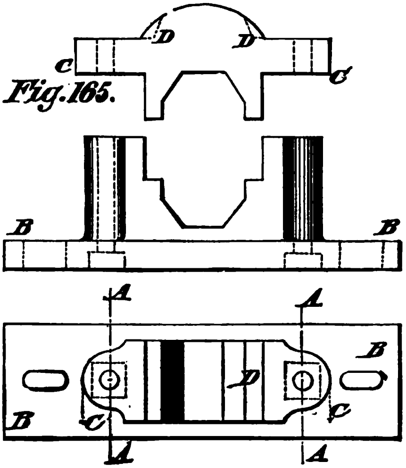
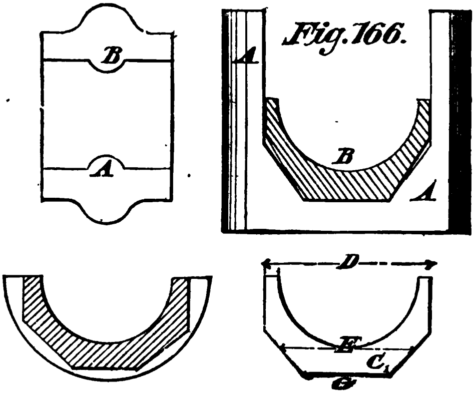


Fig. 165.

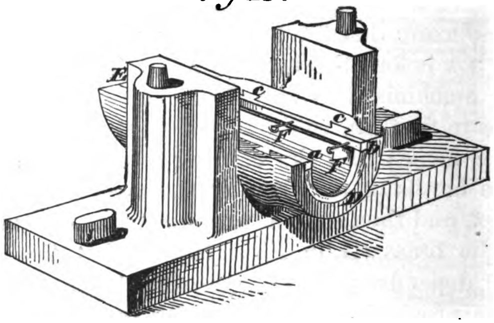
It must now be observed that a hollow or filleted corner appears where the cheeks of the block meet the base; and further, that the recess in the block to receive the brasses is drawn to a depth coinciding with the height of the hollow or fillet. It will be advisable, therefore, to prepare a piece of the length from C to C, and to shape the ends to the outline of the cheeks, and, forming in this piece all the fillet, the cheeks may next be prepared of a thickness from the line A to D. These must be strongly fastened, and are best mortised clear through the base, and glued fast. Two semicircular pieces must be turned for the portions outside the lines A A, and three-cornered pieces must be fitted in the square recess, to make it octagonal as required. Nothing now remains but to attach the core prints, and make a suitable core box. A half box will suffice for the cap bolt-holes, and a whole one for the holes in the base, as the cores for these latter will stand on end. To make the cap, we take a piece of timber large enough to make that portion of the cap that is above the line C C; and we line or mark out the form of the cap on both sides (using a center line to make the two sides correspond), and pare away the surplus wood down to the lines. The pieces below the line C C are to be afterwards glued and nailed on. It is advisable to cut out a recess in the top of the cap, as shown in Fig. 166, at A B, to afford convenience to the machinist in using the wrench upon the nuts. Fig. 167 is a sectional view of a pattern for the brasses; and this pattern requires great care in its making, for the following reasons: Brasses of this kind, and of a size not larger than is required for a journal about ten inches in diameter, can be fitted in much quicker by chipping and filing than by any other method; and in any event, a great deal of labor and metal can be saved by constructing the pattern of the necessary shape. Since, however, to give the required shape without the reasons therefor, would not convince the reader of the correctness of the method, I will fully explain the two. It has been stated in former remarks that brass castings are smaller than the patterns from which they are cast, by an amount of $\frac{1}{8}$ inch per foot, which is due to the contraction of the metal in cooling. Now, in addition to this contraction, the casting of a brass also contracts across the bore. Suppose, for example, that, in Fig. 166, A A represents a locomotive axle box, and that B represents the brass for the same, the two being shown in section, while C represents the casting for the brass. Beginning, then, with the casting, C, we have the following considerations: The diameter



of the brass across D will be less than it should be, because such castings always close in that direction more than is due to the contraction in cooling. As a consequence of this, the top of the bevels, as denoted by the dotted line, E, becomes less than it should be; and when the brass is fitted on the sides, and let down in the box ready to fit on the crown and on the bevels, the bottom of the brass will bed, and the bevels will not, as shown in the illustration. Now supposing the angles to be at the top $\frac{1}{16}$ of an inch from the bevels of the box, then it will require about $\frac{1}{8}$ of an inch to be taken off the bottom of the brass to let the sides come to a fit; whereas if, when the bevels of the brass contact with the bevels of the box, the bottom of the brass were $\frac{1}{8}$ inch from the bottom of the box, $\frac{1}{16}$ inch taken off the bevels would let the bottom come home. It is then easy to see that the pattern maker should make the pattern so as to allow for the shrinkage across D, and at the same time insure that the bevels of the brass shall contact with the box before the bottom does. Then, by the time that the machinist has taken sufficient off the bevels of the brass to fit them to the bevels of the box, the crown will come home; and the best way to insure this is to make the bevels of the brass of the same shape as those in the box, and then take a certain amount off the crown face of the brass (G, in Fig. 166). What this amount should be, depends upon the angle of the bevels. For bevels of 45° the proportions should be, for brasses of two and less inches bore, a full $\frac{1}{32}$ inch; for brasses having a bore of from two to four inches, $\frac{1}{16}$ inch will answer; while, if the bore is from four to seven inches diameter, $\frac{1}{8}$ inch will be a good proportion. If, however, the bevel is greater, these proportions may be increased. This is an important matter, and should never be overlooked or neglected, since it reduces the labor of fitting the brasses by at least one half.

The method to be pursued to make the pattern for the brass, is as follows: Take a piece of wood of sufficient size to form the body of the brass, and make it of the necessary size and form, observing the direction above given as to the bevels; and make the flanges by turning the two halves in one, as explained in a previous example, omitting to turn out the inside, as this would effect no saving, and such boring would weaken the flange, and render it liable to split in attaching it to the body of the pattern. To fasten the flanges, glue them on; and when dry insert brads, setting the flanges by lines. Then pare out the flange even with the bore of the brass. In many cases brasses are dispensed with, and Babbitt metal is employed in their stead. The requisite form of casting for this purpose is shown in Fig. 167, the Babbitt metal being contained within the thin ridges which extend all around the edges of the half circular bearing. In addition to this, however, the machinist sometimes drills small holes in the cavity for the Babbitt metal. The ridges are cast solid with the box, and the two at the end (D and E, in Fig. 167) make no difference to the molding, since they will leave the sand readily and easily. But the ridges or strips that extend lengthwise of the bearing, must be made detachable

Fig. 167



from the pattern, the strips referred to being held in position by the dovetails shown at C. The recesses to receive the dovetails are first cut out, and the dovetails are made to a neat fit therein. Then we take the strips required to form the ridges, and having just spotted the faces of the dovetails with glue, while they are in their places, we press the strips against them for a moment, and adjust the strips and leave them in position for the glue to dry. By this means the dovetails are fastened to the strips exactly in the required position. When dry, the strips with the attached dovetails may be withdrawn from the pattern, and should then be more securely fastened together by the addition of screws or nails. In many cases, wires are employed in place of the dovetails; they being inserted, as shown in Fig. 167, at F; and when they are used, it becomes a consideration whether the molder can conveniently extract them. If he can, they are preferable to the dovetails, as these latter are sometimes apt to stick.

Bearings of this class (Babbitt metal) are often formed in the framework of a machine, or in other patterns that do not permit of being molded in the direction suitable for the above example. Fig. 168 represents such an example, which requires to be molded in the direction denoted by the arrow. It will be advisable to core out the whole space for the cap and bearing, the core box in this case being fitted with the strips in a manner similar to that above described for the Babbitted pillow block. The pattern in this case is made as shown in Fig. 169, the space for the bearing being blocked up, and the block extending through, as shown

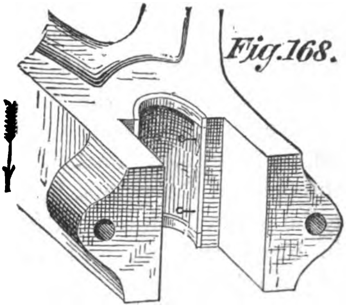


Fig. 168.

at A, to form a core print. The core box shown beneath may be, in the smaller sizes, cut out of the solid wood, the part B being made thick, because it includes the thickness of the ridge on that end, and also the depth of the print, as shown at A. The reason that the block or core print protrudes at C, is, that a ridge may be formed in the mold to steady the core while inserting it in the mold; and the depth of the core box, at E, must be made to suit it. It will be noted that the core prints, at F F, are carried to the top of the pattern; and it will be readily perceived that they must be so made in order that the pattern may lift from the sand. Then, after the mold is made, the core for the hole is first inserted, and then a small core is fitted into the recess in the mold; and thus is the top part of the recess (above the core print) stopped off. The circles marked on the faces of the prints, F, are to be painted on the pattern in black varnish, and their purpose is to denote that the core proper is round. If these black circles were not made, the pattern maker would

Fig. 169.

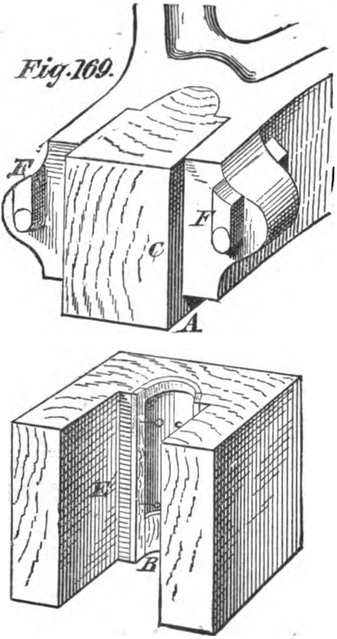
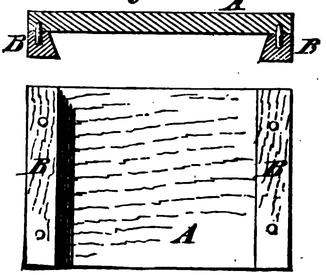


Fig. 170.



require to make a similar circle and cross marks with chalk or pencil, that the molder may know how the core is to be left.

Fig. 170 is a representation of a pattern for a slide; it has the projections simply set on with pegs, to prevent the pattern being locked in the sand. In molding this piece, a false core is laid between these projections. After the cope is lifted, the plate A may be taken out; and after removing the false core, the pieces B B can be withdrawn.

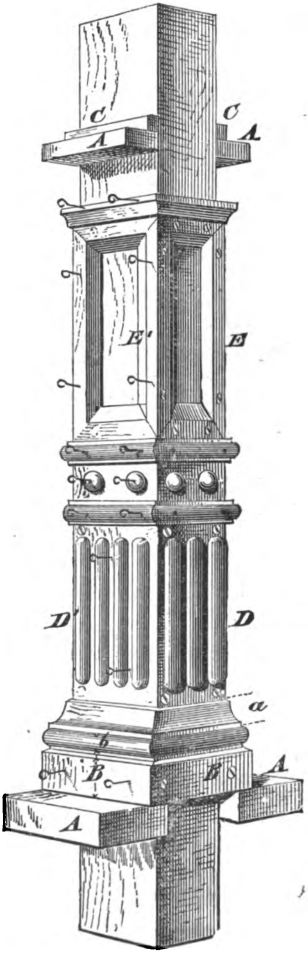
CHAPTER XI.

EXAMPLES IN COLUMN PATTERNS.

Our next example shall be for a square or rectangular column, which, though very simple in construction, yet necessitates a departure from the ordinary method pursued in pattern making—the object being to save the making of an entirely new pattern for every required column. In view of the thousands of columns of this kind that have been cast, it is not to be wondered at that measures have been taken to cheapen the cost of the pattern, and lessen the labor in preparing the mold; but it is to be remarked that no one has been able to invent a permanent mold for this class of work. In cast iron columns, the strict rules of architecture are not rigidly followed. The slight but graceful curve prescribed for every column and pilaster is frequently neglected, and various parts of the column are modified in their contour—to their detriment, as may be easily seen by comparing the details of a stone building with those of an iron one.

Square iron columns are usually made parallel throughout their lengths; while, on the end view, two of the sides incline towards one another, on account of the draft or taper given to the pattern. Round column patterns are not made parallel, but are smaller at the cap than at the base. The curve above mentioned is given to the shaft; but as the pattern is made to serve for all lengths of columns of that diameter, the curve can only, in most cases, be an approximation. In foundries that make a specialty of this class of work, numbers of blocks of various sizes and lengths are kept, and they simply require the addition of such ornaments as the design comprises, which ornaments—such as moldings, flutings, and the like—are often ready to hand, to complete the column pattern. These blocks are, for small columns, made solid; but for large columns they are constructed like boxes or troughs, with pieces filled in at short distances to give strength. (See Fig. 172.) Fig. 171 is a perspective view of a block, mounted with moldings and other ornamentation, so as to form a column pattern ready to go into the sand. The base, B, and its moldings, *a* and *b*, are to be cast solid with the shaft of the column; this, however — as may be inferred from what has been said — is not compulsory. It will be seen that the base forms a guide for the stopping-off blocks, A A, at that end; at the other end of the column the guides, C C, are attached. The distance between the stopping-off blocks, A A, is of course the length of the column, *plus* shrinkage and *plus* the amount left for cutting off to square up the ends of the cast column. The wires shown are for the purpose of holding the ornaments in position upon the block. The ornaments on the face

Fig. 171.



are held by loose pegs, except the cabling, D, and the paneling, E, which are made fast on the face by nails or screws.

Let it be required to prepare a pattern for a column 12 feet long, of 12 inches face, and 14 inches deep, to be of the style shown in Fig. 171. Select a block similar to that shown in Fig. 172, in which the top piece is shown removed, so that the distance pieces may be seen. We will suppose our column to require mounting on the face and one side; then ½ inch or ⅝ inch will be taken up on the face and side by the margins, E, which form, with their moldings, the paneling: therefore, if ½ inch margins are used, the block should measure 11½ by 13½ inches, and ⅛ less if ⅝ margins are employed. The length of the block is immaterial, so that it be not less than 20 inches longer than the column. This excess is for core prints at the ends of the pattern. Lay off upon the block the length of the column pattern; this will be 12 feet + $\frac{12}{16}$ inch for shrinkage + ⅛ or $\frac{3}{16}$ inch at each end for squaring up. Space off upon the block the position of the various members, and apply them as directed. It must be noted that the moldings and base pieces on the face overrun those upon the side, and also extend according to their contour over the side that is not mounted (see Figs. 171 and 173). The reason of this is that by removing these face moldings and base pieces, except the cabling and paneling (which are fast), the molder can make a bevel parting. When the parting

Fig. 172.

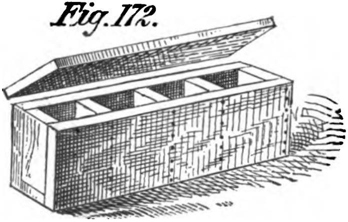
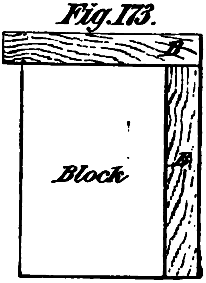


Fig. 173.

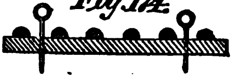


is made, the pieces are then replaced, and will be taken up again by the cope. A rectangular column is invariably molded with the face up, because of the facility such a position gives for supporting the main core by means of the cores which make the openings always formed at the back of these columns.

For stopping off the column to the right length, we simply prepare four pieces, as shown at A, Fig. 171, of a length equal to the depth of the column at the ends, not including the base piece, as that will be stopped off in the cope. In ramming up the column, when in the sand, these pieces are bedded in, in the position shown. Some provision is necessary to prevent them from being rammed out of the perpendicular. This is provided in this case by the base pieces, B; but at the other end of the column temporary strips are bradded to the block, as shown at C. To find the place for these guiding strips, add to the length of the column pattern the thickness of the stopping-off piece, square a line at this point down each side of the block, and nail on the guides outside this line, but with one edge touching it. Columns are often cast without bases or caps—these latter being cast thin, and attached by screws after the columns are set up.

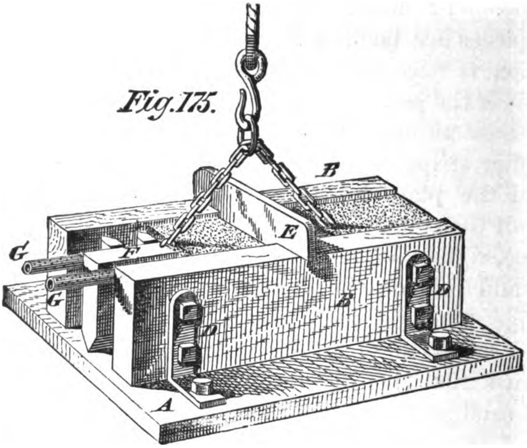
The ornamentation of columns is varied constantly, depending upon the taste of individuals; therefore, it is impossible to lay down precise directions in this matter. It is thought, however, that the above remarks will be of service; and I may add that, in place of cabling, fluting is often employed. This is never to be cut out of the block, but formed in extra pieces. The cabling on the side is made by fastening the strips to a piece of board, and this is attached to the block by wires. Fig. 174 shows this arrangement. Baked or dry sand is not used for the main core of square columns, and we proceed to describe

Fig. 174.



the method of making the green sand core now invariably adopted. Fig. 175 shows a sort of universal core bore, employed for making these cores. A is a cast iron plate, laid upon the floor of the foundry, generally in close proximity to the mold; upon this are set up two stout boards, B, about two inches thick. These boards are adjustable, so as to take in any breadth of face, by the brackets, D, moving along slots in the plate. Nipping screws in the brackets admit of the boards being pressed together on the end pieces, which must be changed for every width of column; the height of the core is regulated by means of the strike, E. On account of the exceedingly fragile nature of a green sand core, it is necessary to imbed within it a strong bar of cast iron, called a core bar, such as is represented at F, Fig. 175. It consists of a strong center bar with pieces cast solid with it, ranged on each side, called wings; the bar itself is made to taper off to a narrow ridge towards the under part, as also are the wings which taper at the edges. The sand, being rammed between these wings, is able not only to sustain itself, but also a

Fig. 175.



small portion extending beyond them — namely, to the correct outline of the core. The bar is generally from half an inch to one inch smaller than the core, as will be seen in the sectional end view, Fig. 177. A notch is cut out of each wing, to admit of the insertion of a perforated tube on each side, for ventilation. The core bar, F, and the perforated tubes, G G, are shown in Fig. 175, imbedded in the core.

Fig. 176.

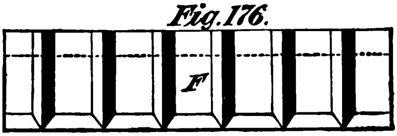
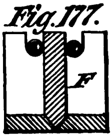


Fig. 177.



As there are not any core prints required to form the openings at the back of the column, the cores for these openings are made in a box not thicker than the intended thickness of metal in the column. Such a box is shown in Fig. 178; though for the sake of cheapness, when the columns are not more than half an inch thick, the core box is sawn out of one piece.

Fig. 178.

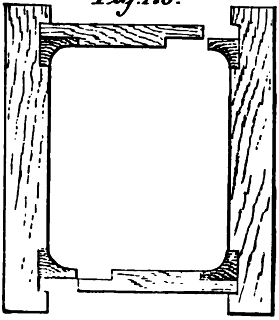


Fig. 179.

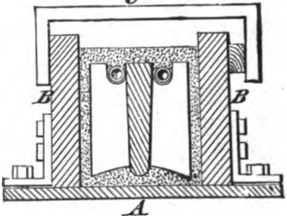


Fig. 179 is an end view of the core box, with core, shown in Fig. 175, but with the addition of the wooden binder, which serves to assist the brackets in holding the sides, B, of the core box together, which is necessary when the core box is very deep.

Round columns are either plain, fluted, or of a mixed design, to agree with the square columns in the same building. Fig. 180 represents a plain round column; but it must be remembered that, even though the shaft be plain, the design of the base and cap may be modified according to taste. In the case of so simple a one as we have illustrated, it would probably be cast solid, as represented; though if of very large size—as those in the crypts of churches, perhaps 18 inches in diameter—a great deal of metal would be saved by simply casting a plain round shaft with the moldings, N and O, upon it, and of a length measured from the lower part of the base to the top of the cap. This casting takes the weight of the building. The base, B, with its molding, B M, and the cap, C, with its molding, C M, are thin castings fixed to the column by screws. P P are the core prints. Little need be said as to the method of preparing a pattern of this description. If small, it will be turned from the solid wood; and if large, it will be lagged or staved up, as we have described in examples of lagging and staving. In any case, the pattern must be made in halves. Some foundries require a half core box; while in others, the core is struck up in the manner described on pages 89, 90.

We may now pass to the consideration of the fluted column, shown in Fig. 181. D is a plan of the peculiar cap required for this kind of column; it is neither square nor round, but of a shape which harmonizes beautifully with the carved work below, all of which, including the cap, is added afterwards, the column being cast a plain round above the member marked N, and also below that marked O. The extension, A, is the part which passes between the joists of the flooring; it is often flattened to admit of this, as shown at C, Fig. 182. B is a section of

Fig. 180

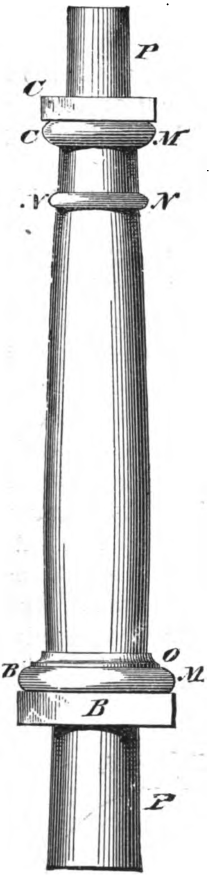


Fig. 182.

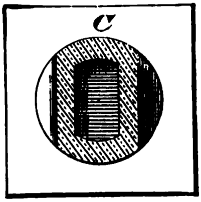


Fig. 181.

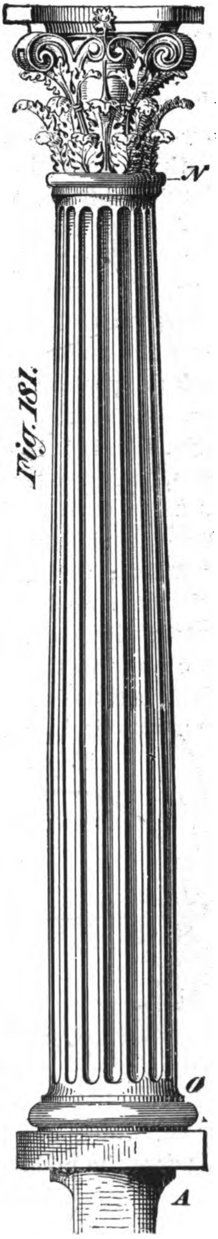
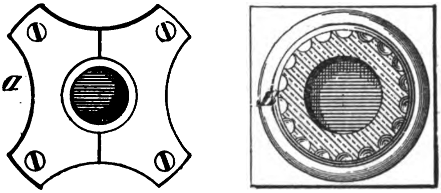


Fig. 182.



the column through the fluted part. It is not thought necessary to show the prints, as they would be similar to those shown in Fig. 180, the lower one being flattened if the extension A were required.

We have now arrived at the most important part of this branch of our subject, and that is, how to make the fluted pattern column so that it may be extracted with facility from the mold; for, by referring to Fig. 181, it will be seen that the rammed sand, by entering the flutes, would lock the pattern down, unless this difficulty were provided for. To overcome this difficulty, we refer the reader to Figs. 183, 184, 185. Fig. 183 is a sectional view of a column, turned extra large at the part intended to be fluted, so as to form a plain core print all around the column. A convenient number—divisible by 3 or 4—of flutes must be taken; we have taken 12 flutes in the half column. A suitable core box must be constructed with, say, four flutes; these cores, when packed around the mold, will core out the flutes in the column. This method is only given because there may be special cases where it would be most suitable; but it is not that generally adopted.

Fig. 183.

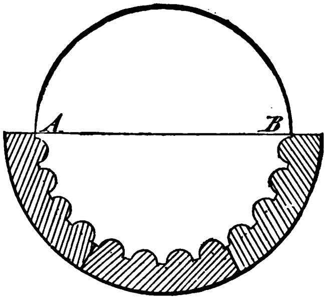
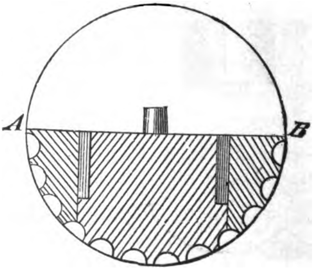


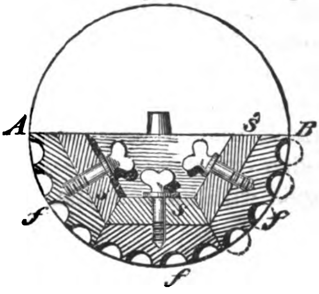
Fig. 184.



In Fig. 184, each half of the column is formed of three pieces, which are held together by taper dovetails; in this case the middle piece is first drawn from the mold and then the side pieces. This method will accommodate any even number of flutes, and is quite practicable; the objection to it, however, is, that the dovetails are liable to stick, and also that, when the middle piece is drawn out, the side pieces sometimes fall into the mold, to its irretrievable injury.

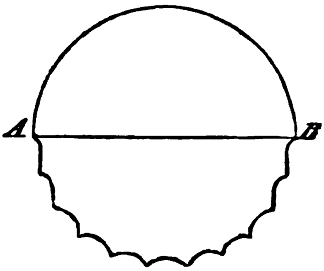
Fig. 185 represents the arrangement in most general use. It is not nearly so expensive as that shown in Fig. 183, nor is it open to the objections mentioned in connection with Fig. 184. The three pieces marked S are the main staves of the column pattern, but the number is not arbitrary. We may take four or any other number, depending on the size of the column; it is advisable, however, to have as few pieces as possible. What we have to do is to notice the direction taken by the pieces as they are drawn out, and if it appears that the flutes do not escape properly, then a larger number of divisions must be made. The pieces marked *f* are the supplementary staves in which the flutes are cut; they are attached to the inner staves by screws, which are removed by the molder, who is then able to extract the pattern. The side pieces, *f f*, are then drawn out, and lastly the lower pieces, the process being, it will be noticed, the reverse of that shown in Fig. 183. In each case, the line A B is the parting line of the pattern, which must always occur in the middle of a ridge and not in a flute. The flutes should be cut out to a half circle, and eased off slightly towards the ridges with sand paper. They must not be in the least undercut, because of the draft in the mold. The pattern should be made as

Fig. 185.



smooth as possible by alternately sand-papering and varnishing, using well worn sand-paper to insure smoothness.

Fig. 186.



In Fig. 186 are shown what are called bastard flutes. Their use gives a cheap but not beautiful style, and they are sometimes employed on lamp posts and columns in the cheaper class of tenement houses. The flutes, it will be noted, are made shallow and of a shape to permit the whole half pattern to be removed from the sand. The flutes are cut out of the solid, the front ones being the deepest, and the side ones so shallow that many of them are scarcely distinguishable.

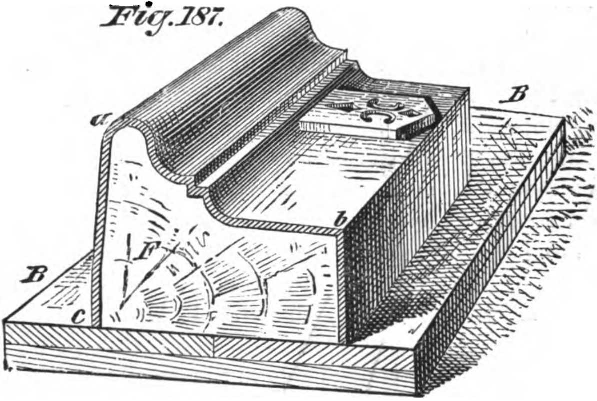
In columns whose designs are of a mixed character, the methods illustrated for fluting are equally suitable for cabling, as shown in Fig. 185, where the cabling is shown in dotted lines; while rosettes, rope moldings, and the like, are either attached by wires, as shown in the illustration of square columns, or they must be cast separately and afterwards affixed by screws, as are many other ornaments whose shapes preclude their being molded solid with the columns.

CHAPTER XII.

EXAMPLES IN THIN WORK.

In the examples we have hitherto presented to the reader, we have supposed the pattern to be of such substance or thickness, as to be able to bear the pressure of the sand being rammed about it in molding, without breaking or altering its form; but this is not always the case. The parts of a stove, for instance, are cast often less than $\frac{1}{8}$ inch in thickness; the same may be said of most of the ornamental ironwork used in architecture, and even cornices and window sills range only about $\frac{3}{16}$ or $\frac{1}{4}$ inch thick. It is true that for this kind of work metal patterns are almost invariably used; but for the pattern maker this is indifferent, as wood patterns have to be made from which the metal patterns are to be cast. Take, for example, the window sill, shown in section in Fig. 187. To enable it to withstand the pressure of the sand, while ramming, we must fill the interior with a form or block,

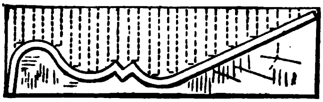
Fig. 187.



shown at F, which is to be used in conjunction with the board B. This form and board are no less useful to the pattern maker than to the molder; for let the form be once obtained of the proper size and shape, and the construction of the pattern is so far simplified as to be merely a covering of this form with wood slightly thinner than the required thickness of metal. Most thin work is made in this manner, especially if the patterns are of such size or shape as to need the joining together of many pieces. It is not the pattern itself that demands our first attention, but rather the form that supports it.

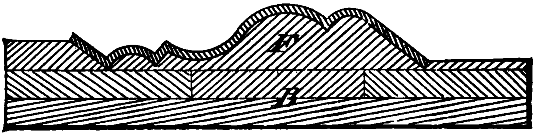
Thin work demands great care and patience, on account of its fragile nature. Scarcely any hold can be obtained for nails; and though the best glue is used, it cannot always be relied upon. Dovetails for square corners, if they are end wood to end wood, will be found very superior to glued joints. Furthermore, as few joints should be made as possible, and the pattern should be well protected by several coats of varnish. In working out thin moldings—as for instance, the portion of the sill from *a* to *b*, which should be of one piece—we plane up a piece of a suitable width and thickness, and trace the outline of the molding upon each end of the piece; then, as it lies flat upon the bench, we work out on one side to the lines which will fit the form, as in Fig. 188, and then, by temporarily fastening the piece to the form, F, to give it proper support, we are enabled to work out the opposite side to the required shape. In working out thin moldings, a circular saw with an adjustable table will be of great assistance, as by its means we may make a series of saw cuts so close together as practically to take out half the stuff, and form an excellent guide for cutting away

Fig. 188.



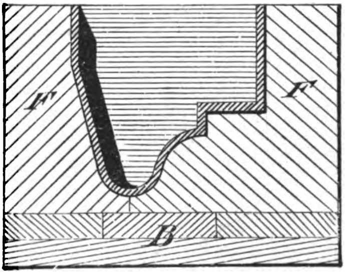
the other half (see Fig. 188). The part from *a* to *c*, Fig. 187, should not be formed by gluing thin stuff together at the obtuse angle, but should be of one piece. Fig. 189 is a section of a cornice lying upon its bed or follower board, B; it may be made of one piece, as in the previous example.

Fig. 189.



In molding work of this kind, the procedure is as follows: The board, B, with the form and pattern, is placed upon a level bed of sand, so that it may not wind or twist under the weight that is to be put upon it, which will consist of the nowel rammed full of sand. The board and nowel are fastened together by clamps, and, the ramming finished, the whole is turned over; the board and form are then removed. There is no longer any necessity for the support of the latter, as the sand, having been once rammed, does not press upon the pattern to its injury, but keeps its position, and becomes a good and sufficient support to it during the ramming up of the cope, which is now placed in position, and the molding continued in the usual manner.

Fig. 190.



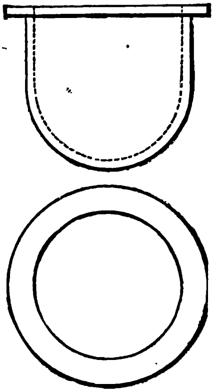
Instead of the form, F, which fills the interior of the pattern, we may provide a strong enveloping form, as shown in Fig. 190; the difference is that the reverse side of the casting will be uppermost as compared with the other case. The form must fit that side of the pattern which we wish to come next the cope. Forms of an irregular or difficult shape are often advantageously made by simply pouring plaster of Paris into the patterns for which they are intended. A great deal of thin work is formed by dry sand coring, often from necessity; but when practicable, the dry sand core is discarded, and the pattern made to leave its own core. This insures greater accuracy, is cheaper, and causes the interior surface of the casting to be the same as the exterior. When dry sand cores are employed, there is no difference between thin work and thick, and therefore the methods described in former pages are a sufficient explanation of the process.

CHAPTER XIII.

SWEEP AND LOAM WORK.

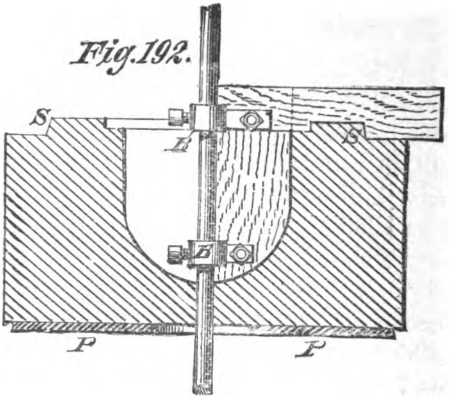
The above title applies to a class of work, generally of large size, in which boards or sweeps, fixed to a revolving spindle, serve instead of patterns to form the molds. This arrangement, of course, will only produce circular molds; patterns may, however, be used in conjunction with the sweeps, as we shall endeavor to illustrate further on. The spindle above named is a light vertical shaft, revolving in a step below and a bearing overhead; when a part of a mold has been swept up, the spindle can be raised out of the step sufficiently to enable the work to be removed and preparations for the next piece substituted.

Fig. 191.



Let it be required to produce a casting, such as is shown in Fig. 191—a sort of pan or boiler, often used. Fig. 194 is a sectional view of the mold complete. It is formed of two parts, the lower being called the "seat," and the upper the "cope." Figs. 192 and 193 illustrate the method of forming each of those parts. The material used by the founder is called loam—a clayey, plastic composition, very soft. After a certain quantity of this material has been piled up, the sweep is revolved; it shears down the high places and indicates the holes or hollows. Into the latter more material is placed, and the sweep is passed round again; and so on until the job is perfected. It will be noticed in Fig. 194, that the two parts of the mold are retained in their proper position by a projection on one fitting into a recess in the other; this is the seat proper, and is indicated throughout by S S. The pattern maker's part is to form the sweeps, which he does in the following manner: On a piece of board of the proper thickness for a sweep—the size of which depends on the size of the work—he draws an outline of the job, interior and exterior, from the center outwards; and beyond this he lays off his seat, as shown at Fig. 193—the dotted lines representing the interior of the piece. He has then simply to cut away to the interior line, and also the step at S, and one board is finished, unless he knows the diameter of the spindle and the position of the holes in the carrying bracket attached thereto; in which case he is supposed to cut off, parallel with the center line, a portion equal to the radius of the spindle, as a recess for the hub of the bracket, B, and to bore the holes for the bolts. The board, Fig. 192, when reversed, should fit that in Fig. 193 at the lower part, and be of a shape to coincide with the dotted line. Its length must be enough to extend to the center, *minus* the radius of the spindle, as shown in Fig. 192.

Fig. 192.



It will be seen by the lines showing the grain of the wood that the board in Fig. 192 is formed of two pieces, lapped at the corner, to give strength; and, to avoid too much cross grain, battens may be added when it is thought necessary. As I have already remarked, in striking up cores with a horizontal spindle, the working edge of the board should be beveled; and it is hardly necessary to say that the same is applicable in this case.

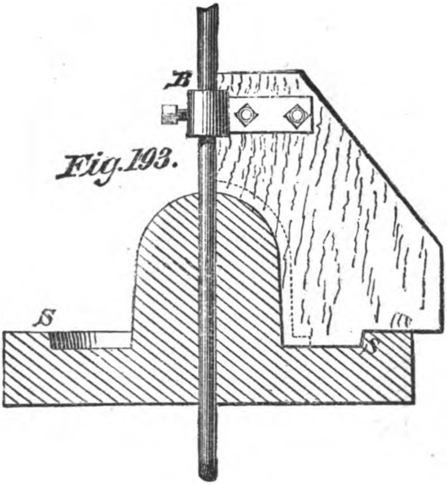
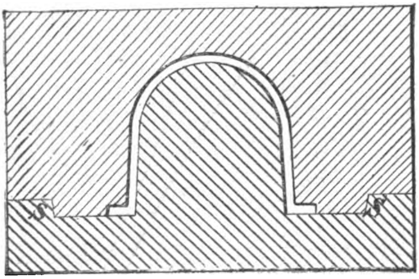


Fig. 193.

Fig. 194.



P P, Fig. 192, is a circular plate of cast iron, used to support the mold while soft; it is not shown in Fig. 193. By the same method, only varying the outline of the sweeps, a large class of circular work may be produced, including vases, speed cones, etc. Sometimes it is necessary to cast brackets, pipes, or other projections, upon the main piece; to do this, patterns must be made of those projections, and

Fig. 195.

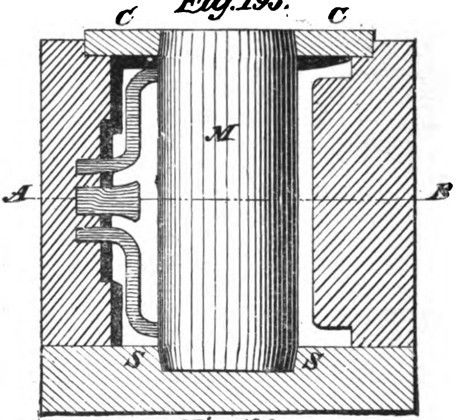
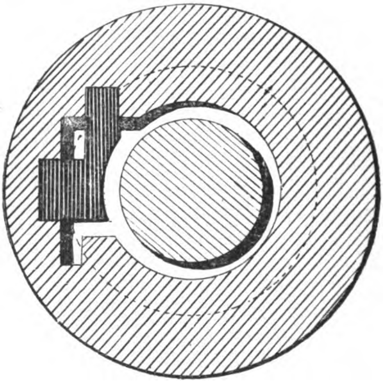


Fig. 196.



as many patterns as there are projections. The height at which it is required to bed in these brackets, etc., must be indicated to the molder by a small V, cut into the sweep; this will produce, as the sweep revolves, a line upon the mold. For the rest, unless simple directions can be given, the pattern maker usually visits the foundry, and assists in placing, or at least in verifying, the position of the pieces. When the mold is sufficiently hard, and before it is baked, these patterns are withdrawn.

A good illustration of the manner in which pattern work may be used in conjunction with sweeps, is furnished in the ordinary engine cylinder. Fig. 195 is a sectional elevation of a complete mold; Fig. 196 is a horizontal section of the same, on the line A B showing the outlet for the exhaust steam. This mold is composed of four parts that are swept or struck up—namely, S S, the seat; A B, the body; C C, the cope, and M, the main core. The latter may be struck upon a horizontal arbor, or formed in a box In addition to the parts above enumerated are the two steam port cores and the exhaust port core, all formed in core boxes. The procedure is as follows: With a board, shown in Fig. 197, the seat S S is struck up; upon this, when dried, is placed a flange of wood. It is set centrally; the seat is also carefully beveled and set by the spindle. A pattern of the slide face, with the parts in which the steam and exhaust passages occur, is set in position on this flange; the top flange of wood is now added, and tem-

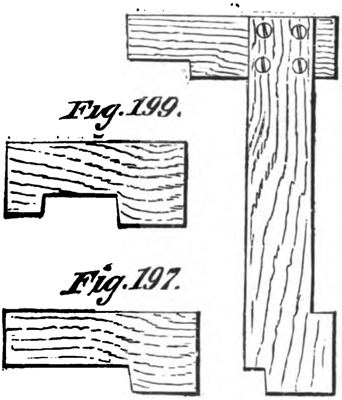


Fig. 198.

Fig. 199.

Fig. 197.

porarily fixed to the slide face pattern, and shored up on the opposite side, so as to maintain it true and level. With the board, Fig. 198, is formed the body A B; the shape of the exterior of the mold is not important; it is left rough, but some mark must be made so as to be able, after removing it from the seat, to restore it to the position as before. When the body has dried sufficiently, the pattern flanges and slide face are withdrawn, the body being lifted from the seat for this purpose by means of bolts passing through it, and terminating in a cast annular plate at the bottom. The projecting flanges on the slide face are attached by wires and dovetails; otherwise the piece would be locked in the mold. The side print for the exhaust port is attached also by a loose wire. Fig. 199 is a board for sweeping up the cope, C C. The whole of these boards are represented as carried to the center of the spindle; allowance must, therefore, be made for the spindle and bracket. For very large cylinders, wood flanges are not used, the sweeps being made to a shape to perform the whole of the work.

CHAPTER XIV.

GEAR WHEELS AND WORM SCREW.

We now approach a class of work in which the fullest amount of care and attention on the part of the pattern maker, for the attainment of accuracy, is exceedingly desirable. Patterns for wheel work, clumsily constructed, may be positively worthless, or may at least give rise to great loss of time in the fitting shop, in correcting the defects in the castings taken from them. It is not our purpose to enter into the various methods of arriving at the proper form or curvature that is to be given to the teeth, as that is a subject quite extensive, and a study in itself. What more particularly concerns us, is the general construction of the patterns from designs furnished.

Gear wheels are of two kinds, spur and bevel; the former for transmitting motion when the shafts are parallel, and the latter to be used when the shafts are inclined to each other. When the teeth of a bevel wheel are inclined at an angle of 45° with the axis, that wheel is called a miter. Skew bevels are wheels suitable for shafts that are inclined to each other, and are not in the same plane. Pinion is a distinctive term, applied to the smaller of a pair of gear wheels, when there is a great disparity between them; or it may mean generally a small gear wheel.

Fig. 200 is a plan and section of the pattern of a spur wheel and pinion, such as is usually supplied to workmen. The plan exhibits the form of the teeth and pitch, with the size and number of arms. The sectional view shows the breadth of face, depth of hub, and ribs on the arms. In the construction of gear wheel and pinion patterns, the particular method to be adopted, as also the material to be used, will depend upon size and the service expected to be got out of the patterns. Mahogany, dry and straight grained, is an excellent material for wheel patterns; but for large work it is too costly. In some cases the teeth are worked in mahogany and fixed to a pine body; in the majority of cases, however, pine is the only material used. The pinion may be carved out of one piece, or it may have the teeth attached to a hub; and if the latter, then the teeth may be held by dovetails, or they may be simply glued or nailed. If the pinion is so deep in proportion to its diameter as to be strong enough, and not more than 5 or 6 inches diameter over all, it may be cut from the solid. In this case, the grain of the wood must lie in the direction of the teeth. For turning the piece we must use a chuck or face plate, smaller than the pinion is at the bottom of the spaces, so as to be able to trace circles on both sides by the motion of the lathe; if such a face plate is not at our disposal, we may bore a hole in the piece to be turned, and fit to it an arbor of hard wood. Having turned the pattern, trace upon it very fine circles to indicate the pitch line, the line for the roots of the teeth, and (if required) circles for the centers used in tracing certain peculiar forms of teeth. All these circles are to be traced on both sides of the pattern, and draft is to be allowed by making the circle for the roots of the teeth a little smaller on one side than on the other, and also by turning the piece slightly taper. The pinion is now to be pitched out, on one side, very accurately; this is sometimes a matter of no small difficulty, for, having passed round with the compasses a few times, the points are liable to slide into previous impressions, giving rise to error. For this reason the pattern maker does not allow the points of his compasses to fall where he intends the center of the teeth to be, until he has obtained the correct division, which is known by the compass point, after having made the tour of the circle, falling exactly into the starting point. He now proceeds to lay down the centers of the teeth, and to delineate their size and form; then, by squaring across the face, the points of the teeth are transferred to the other side; the teeth are then outlined on that side, and the intervening spaces cut away exactly to the lines.

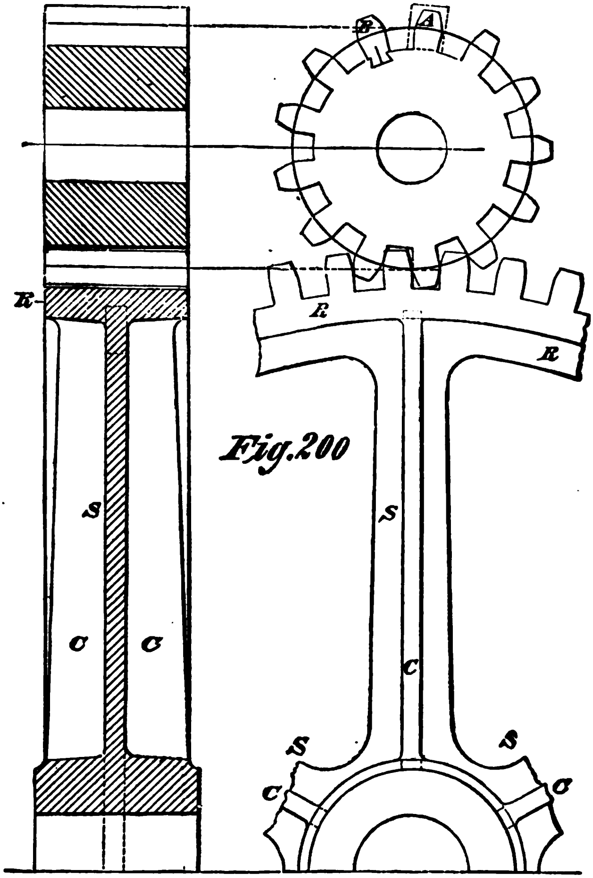
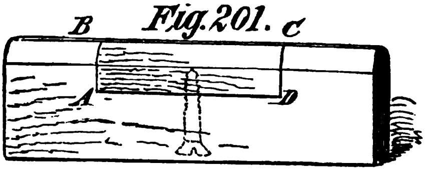


Fig. 200

For a large-sized pinion, the usual method is to build up a hub or body with quadrants, breaking joint at each course or layer; the body is then turned, and the circumference pitched off to the required number of teeth. Blocks of hard or soft wood, planed nearly to the size of the teeth and hollowed on the side that goes next the body, are to be glued on and set to the lines made on the surface of the body when it was pitched off (see tooth marked A, Fig. 200). When the glue has properly set, the whole is replaced in the lathe and turned off, the same as for a solid pinion; the lining-in will also be a repetition of the process above explained. Another method is to fix the teeth on dovetails, as at B, Fig. 200; but as this is very seldom adopted for spur pinions, it will be more in place to describe it when dealing with bevel gear.

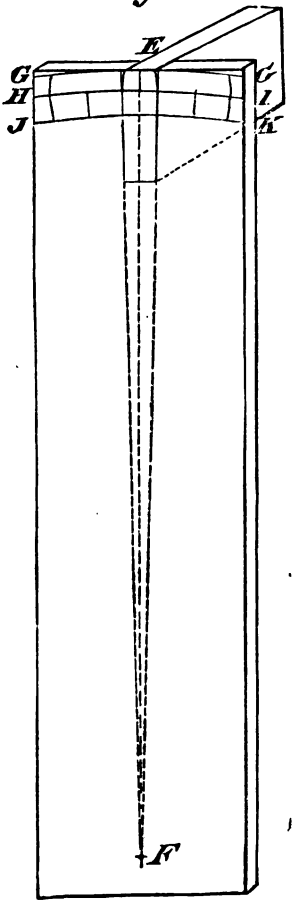
We now proceed to the construction of the wheel which, in our illustration, has six spokes or arms, marked S; the rim, R, must of course be built up in segments; and when we have reached to the height of the top of the flat arms, we should turn the inside to the finished size, and cut in the arms, as shown in Fig. 200, the rest of the building can then be proceeded with. To avoid here useless repetition as to the details observed in building or in preparing the arms, the reader is referred to Figs. 132, 133, 134 and 135. Having turned the body of the wheel, both inside and out, we proceed to attach, on each side of the arms, a hub, so as to form the whole hub, as in Fig. 200; the ribs, C, are then fitted, and lastly we complete the body by filleting the corners. For the teeth there is but one method that is usually adopted, and that is to form them in a box as follows: Plane a piece of hard wood, as in Fig. 201, some five or

Fig. 201.



six inches longer than the teeth, and about three inches wider; the thickness is not to be less than that of the tooth at its thickest part. The ends of this piece must also be planed; from the edge, B C, gage the line, A D, the required depth of tooth. Lay off, about in the center of the piece, the distance B C, equal to breadth of face of the wheel, and make two saw cuts, B A and C D. Let this piece be now let into a piece of planed board, Fig. 202, which is an inch or so longer than the radius of the wheel at the tops of the teeth. This piece is to fit tightly into the mortise, which is made equally on each side of a center line on the board. Take now in a trammel the radius of the wheel at the top of the teeth, and mark off, from the outer edge of the hard wood box, the distance E F on the center line of the board. The point F represents the center of the wheel. Take the radius of the wheel at the pitch line, and also at the roots and points of the teeth; and with these distances describe the arcs G G, H I, J K, and such other arcs as may be necessary, on which to take the centers for describing the correct form of the tooth. Complete the delineation of three teeth, or at least the center one, which will be upon the hard wood box;

Fig. 202.



reverse now this box, and draw the outline of the tooth upon the other end of it; remove the piece from the mortise, and plane off to the shape of the tooth as drawn; remove the portion B A D C, Fig. 201, and the box is ready for shaping teeth in. Such teeth during the process are held by the screw shown.

Select for the teeth, lumber very straight in the grain, and rip off a number of strips about two or two and a half feet long, of a width and thickness (when planed) slightly fuller than the required teeth, and hollow one edge to fit the curvature of the rim of the wheel. Saw the strips into pieces a trifle longer than the teeth, and plane the ends so that, when finished, the length of the pieces is exactly equal to the breadth of the rim. This latter process is most rapidly performed by placing some eight or ten side by side in a frame, and, if necessary, tightening them by a wedge and nipping in the vise (see Fig. 203). The frame must be equal in width to the length it is required to make the pieces, and care must be taken not to diminish this width, as is sometimes done. In planing a number of teeth, it perhaps is as well to black-lead the frame where it is apt to be planed; this will at least show when

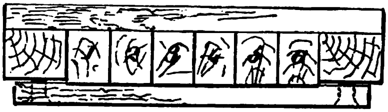
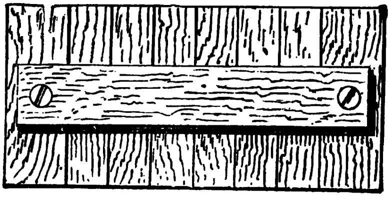
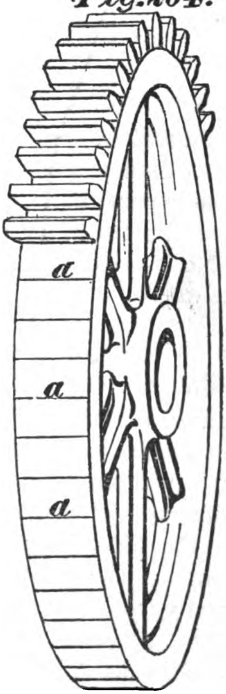


Fig. 203.



damage has been done. The blocks are now severally shaped to the proper contour in the box, Fig. 201, particular attention being paid not to shave away the box in shaping the teeth; for this reason it is well to have an extra plane, very finely set, to finish with. The rim of the wheel having been divided according to the number of teeth required, and lines squared across its face at *a*, Fig. 204, the finished teeth are glued on exactly to the lines. Only a few spots of glue should be applied, so that little or none may exude and hide the line that we pose the teeth by; when the glue has perfectly set, the teeth should be additionally secured by nails. If the above processes are followed up with proper care, the teeth will all be found evenly set around the wheel; nevertheless, it is only right to verify their position with a pair of calipers, while the glue is yet soft.

Fig. 204.



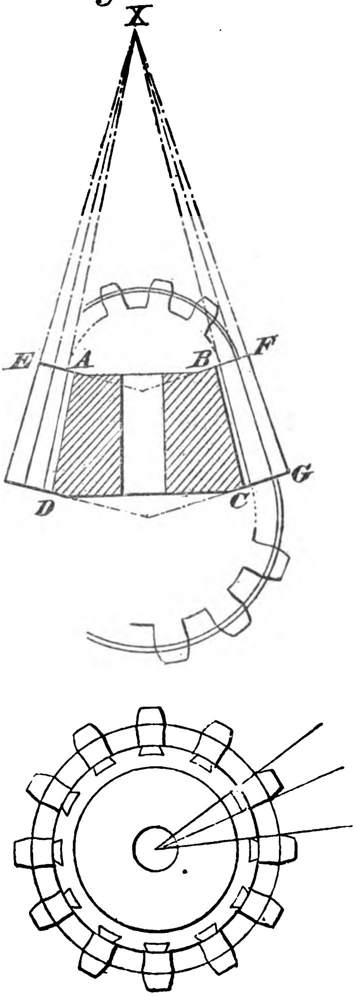
Very large wheels, or even those of moderate size, when difficulties of transportation are anticipated, are made by bolting together a number of sections. A section usually consists of an arm and two equal portions of the rim, one on each side of it, so as to have a joint midway between each pair of arms. However this may be, one thing must be strictly observed, namely, to have the joints always in the center of spaces; therefore it is sometimes necessary to employ unequal segments or sections, in which case the pattern is made to the longer segment; and when these are cast, the flange is moved to suit the shorter one, and the superfluous teeth are stopped off in the sand. This saves cutting the pattern, which remains good for other wheels, when required. The extremities of the arms, which are to be screwed to the hub, are provided with flanges for this purpose, the hub being flattened to accommodate them. A great deal of nicety is required in constructing wheels on this principle, as the spaces between the teeth at the joints must be neither wider nor narrower than at other parts.

BEVEL WHEELS.

"He who can make a good bevel wheel is a good pattern maker." That was once the saying; but the system that divides a trade into specialties is now growing to be the general custom, and it has robbed the expression of half its truth, for there are many good pattern makers who have been engaged all their lives in specialties remote from bevel wheel making. We give the saying, however, merely to show the importance that has always been attached to work of this kind, not undeservedly. A pair of bevel wheel patterns, fresh from the workman's hand, especially if of mahogany and nicely varnished, excite general admiration. It is a job easy enough to do; but you must know the way: that way is what I shall endeavor to elucidate.

Fig. 205 is a sectional elevation and plan of a bevel pinion; the construction of the body does not differ materially from that of a spur. We may commence building up, if the pinion is of such size as to require building, from the small side, A B, for the reason that it is desirable and convenient to turn the part, where the teeth are to be, last, when the building is completed; or if it is a solid piece, we begin by turning off to the line, D C; then reverse on the chuck and turn A B, making a slight recess for the core pivot; set a bevel to the angle, A B C, on the drawing, and turn the circumference to it and at the same time to the required diameter, making it perfectly true and straight for the reception of the teeth. Very little, if any, sandpapering is to be done on this part—it destroys the evenness of the surface. With a fine tracing point, and while the lathe is in motion, mark a line near to D C on the circumference, or, properly speaking, the face. Upon this line the pitching or dividing is made, to determine the position of the teeth; divide this line into as many parts as it is desired to have teeth. It often happens in performing this division that, having passed the compasses around the piece, we do not fall exactly into the starting point, but yet are so near that we cannot shift the compasses, even if they

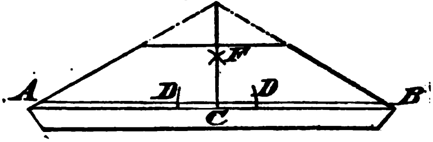
Fig. 205.



are furnished with slow-motion screw, without making the error greater. The usual way of overcoming this difficulty is to give the compass points a few slight rubs upon the oilstone, inside or out, according as we wish either to enlarge or diminish the distance between them.

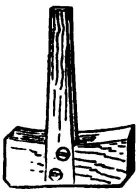
When a pair of bevel gears are geared together, all the teeth on each wheel incline towards a single point; this point is where the axial lines of the shafts would meet if produced. In order to give this direction to the teeth of a bevel wheel or pinion, we must set them square; but to an article of the shape we have produced, an ordinary square cannot be applied in this case, and the workman calls to his aid one of the simplest problems in practical geometry—namely, to erect a perpendicular to a given line. This is illustrated in Fig. 206, where the whole outline is supposed to represent the turned body of the pinion.

Fig. 206.



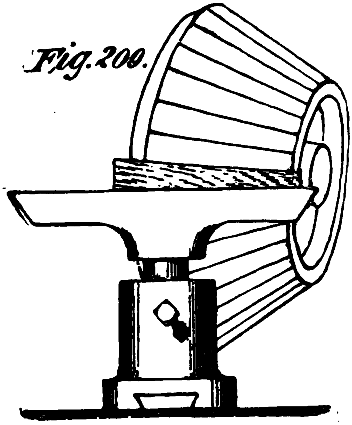
A B is the line passing around it, of which we have previously spoken. In it take any point, C; it may be one of the points already made in pitching off. With C as a center, and at any distance convenient, mark D and D; with D and D as centers, and at any suitable distance, mark the arcs which intersect at the point F. Join F C; it is the perpendicular line required. As it would be too troublesome to go through this operation for every tooth on the wheel or pinion, a square has to be made, such as shown in Fig. 207; the back is generally a piece of pine gaged to fit the edge of the rim or face; a hard wood blade is screwed to it, so that, when the back is applied to the rim, the blade may be made to coincide with the perpendicular line F C; all the rest of the perpendiculars required at the points of division are traced by this square. Another method, even more simple, is to plane a piece of thin wood to lie upon the hand-rest of the lathe, so as at the same time to coincide with the perpendicular drawn by the aid of the compasses; it is then correct for tracing the others. This arrangement is shown in Fig. 209.

Fig. 207.



If we intend simply to glue and brad the teeth, we proceed to make blocks, a little larger every way than the teeth require to be, hollowing out one side to fit the cone of the body of the pinion. These blocks are glued on to the lines; and when the work is set, it is returned, this

Fig. 209.

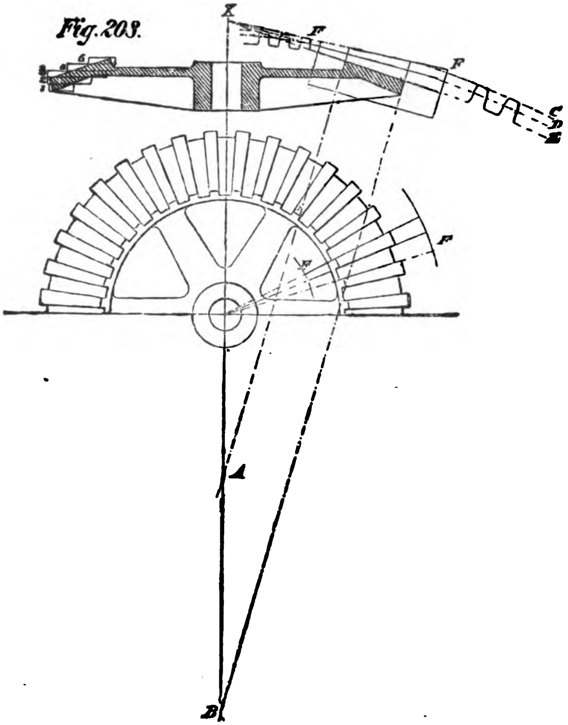


time setting the bevel to the angle E F G. A pitch line must be traced on each side; redivide and draw in the outline of the teeth on the larger side; then, by the methods already described for making perpendiculars, transfer the points of the teeth to the small side; then complete the outline, following out the same principle adopted in tracing the large side—that is to say, taking corresponding centers and distances proportionate to the diminished size of the small side of the cone, as shown in Fig. 205, where the large and small ends of three teeth are set out.

When the subject of spur pinions was under consideration, I deferred making any remarks upon the attachment of teeth by dovetails, until bevel gear should be treated on. Let us now consider the advantages and disadvantages, if any, of this mode of fixing the teeth. We have long ago mentioned the property which wood has of altering its size according to the dryness or humidity of the atmosphere, which alteration, though considerable across the grain, is very slight in the direction of its length. Hence, when teeth are glued to a body, the grain of which crosses that of the teeth, there will be a movement between the two when the pattern is subjected to a change in dampness or dryness; the dovetail allows freedom for any movement from these causes, retaining the tooth in its position under all circumstances. Should the mold happen to break down in the act of withdrawing the pattern, it may be restored to a considerable extent by knocking out a few teeth, placing them in the damaged impressions left by the pattern, and bedding up the sand around them. It sometimes happens that the teeth of a bevel wheel or pinion will be too much undercut to leave the mold without damaging it; this method will admit of the teeth being withdrawn in detail, after which the pattern can be lifted without difficulty. To counterbalance these advantages must be mentioned the extra cost inseparable from this method of fixing the teeth. This, however, is really a small matter when dealing with pinions; and, therefore, bevel pinions usually have their teeth attached by dovetails, excepting those of small size. If it is decided to use dovetails, we proceed as follows: The body of the pinion has been turned and divided, and the perpendiculars all finely drawn in. Cut out of thin wood a piece of the size which the dovetails are intended to be, which is such that a small margin of tooth may be left on each side; set the piece on the rim, at a distance from a perpendicular equal to the margin allowed; set it by the square, shown in Fig. 207, as the dovetail must have such a taper that its sides may both tend towards the point X, before alluded to, namely, the intersection of the axes of the shafts. This will be the case if, when one side of the dovetail template has been set square, the other is square also. By this template, lines for all the dovetails are scribed on the face; the depth is laid off on the drawing by lines tending toward X; and from this the depth of each end of the recess may be gaged on the pattern. No curvature is given to the bottom of this; it is pared out flat with the chisel. The dovetails are now fitted, and left projecting above the face; they are driven moderately tight; the projecting parts are then turned off level with the rim.

We have now to go through the same process as before described for making and attaching teeth. When the glue is well set, each should be knocked out, numbered, and the dovetail bradded. Fig. 208 is a section and half plan of a bevel wheel. In the latter the shape of the teeth is not shown, but merely their thickness at the pitch line; in the sectional view, a few teeth are laid out in profile upon arcs struck from the centers, A and B, which are the points of intersection of perpendiculars from the ends of the teeth (at the pitch line) and the center line. In the section on one side is shown a series of rectangles, numbered from 1 to 5; these represent the segments of which the rim is composed. It is true that they might be made more nearly to approximate to the shape of the rim by sawing them to a bevel, but a machine suitable for this is not in every shop; and when it is considered that the segments themselves are usually not more than $\frac{5}{8}$ inch in thickness, it will be seen that the additional complication counterbalances the saving in lumber and time in turning. If, however, the wheel is very large, or where thick segments are employed, we may

Fig. 208.



advantageously saw the segments to a bevel. The method described for turning the bevel pinion is exactly suitable for the wheel; the arms will be checked together, but need not be built into the rim, unless we desire an exceptionally strong pattern; the obliquity of the rim enables us to get a good purchase, by means of screws through the end of each arm into it. Care must be taken to have the ends of the arms each to bear properly on the rim; otherwise the rim will be thrown out of true in screwing.

It will be remembered that, in treating upon the spur wheel, we had, in forming the box for shaping the teeth, simply to draw out on each end the natural size of the tooth, that is, if we except a slight diminution towards one end for draught; but the conical form of a bevel wheel gives a little extra trouble. In Fig. 208 the tooth proper is of the length of the face of the wheel, as seen in section. Now all lines bounding the teeth must converge to the point X; so if we take F F to represent the length of the box, we must strike out upon the large end an enlarged, and upon the small end a diminished tooth; then by planing to these lines we shall have formed such a box that any piece shaped in the gap formed in it, will be of the proper size and shape for a tooth. It would confuse our engraving too much were we to attempt to show the enlarged and diminished tooth on the ends of the box; but the principle is easily understood, as we have but to follow out whatever method has been adopted on the drawing for producing the tooth curves.

THE WORM, OR ENDLESS SCREW.

A worm pattern, when cut by hand, involves a slow and tedious operation; and even with the utmost care we can scarcely expect to produce an article so perfect as it would be if cut in a screw-cutting lathe. But however well adapted the screw-cutting lathe may be for producing good screws in metal, it will not be found to give such good results when wood is the material to be operated upon; this may be accounted for by reason of the high speed required to make a clean job with wood in a lathe, which is altogether incompatible with the working of the gearing necessary for cutting screws, at least of such fast pitches as are usually required for worms. Besides, special tools must be made for use in the lathe, conforming to the shape of the tooth; for a worm is really one long tooth wound about a cylinder. There are a few other minor difficulties attending the cutting of a wooden worm in a screw-cutting lathe; and when all are considered, it is doubtful if there is much gain over the old-time hand method. We will, however, describe both:

Let Fig. 209 represent the complete pattern. To make it in either way, take two pieces, each to form one half of the pattern; peg and screw them together at the ends, an excess of stuff being allowed at each end for the accommodation of such screws or dogs, if the latter are more convenient, as they might be in a large pattern. Turn the piece down to the size over the top of the thread, after which the prints, P P, are turned. Supposing it to be determined to cut the thread in a lathe, we must have ready a few tools adapted for the work; the first of which is the parting tool, very similar to a parting tool for brass, Fig. 210—namely, flat and level on the cutting face, but with a great deal more bottom rake, as strength is not so much an object, and the

Fig. 209.

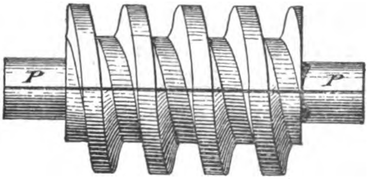
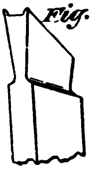


Fig. 210.



tool is more easily sharpened. We have also in addition a little projection, like the point of a penknife, formed by filing away the steel in the center; these points are to cut the fibres of the wood, the severed portion being scraped away by the flat part of the tool. We must not forget to give a side rake to the tool corresponding to the pitch we have to cut; and the width of the tool is to be a shade narrower than the space in the worm at the narrowest part, which is generally at the root of the tooth. Having suitably adjusted the change wheels to the pitch required, we drive down the parting tool until the leading points are on a level with what is to be the bottom of the spaces; a parting tool without cutting points is now adjusted, and the space made of the required depth. We now have cut a worm with a square thread; and it remains to finish to the required form of tooth. To do this, some have essayed a tool such as shown in Fig. 211; but this will not work, for the reason that it is end wood which we have to cut. Were we cutting across the grain—as, for instance, in making the groove with the parting tool—then the one shown in Fig. 211, which is nothing but a scraper, would act very well. The tool shown in plan and section, Fig. 212, has a keen edge imparted to it by piercing a hole through the steel and filing to a bevel; it must then be nicely oilstoned. The only objection to this tool is the difficulty of sharpening it. We ought not to suffer both sides of the tool to cut at once; in fact, the tool itself should not be made quite so wide as the space it has to finish. Furthermore, if the pattern is very large, it will be necessary to have two tools for finishing—one to cut from the pitch line inwards, and the other to complete

Fig. 211.

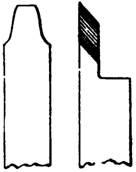
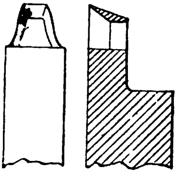


Fig. 212.



the form from the pitch line outwards. It is advisable to use hard wood.

If it is decided to cut the thread by hand, then—the pattern being turned as before—separate the two halves by taking out the screws at the ends; select the half that has not the pegs, as being a little more convenient for tracing lines across. Set out the sections of the thread, A, B, C, and D, Fig. 213, similar to a rack; through the centers of A, B, C, and D, square lines across the piece. These lines, where they intersect the pitch line, will give the centers of spaces on that side; or if we draw lines, as at E, F, through the centers of the spaces, they will pass through the centers of the teeth (so to speak) on the other side. In this position complete the outline on that side. It will be found, in drawing these outlines, that the centers of some of the arcs will lie outside the pattern. To obtain support for the compasses we must fit over the pattern a piece of board, such as shown by dotted lines at G H.

Fig. 213.

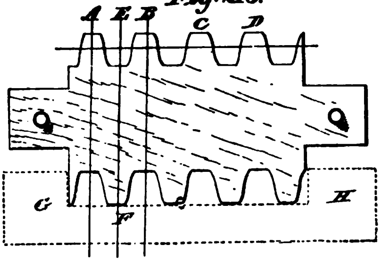
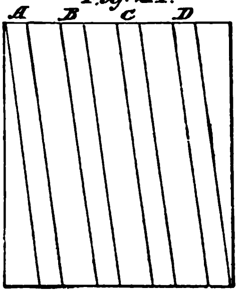


Fig. 214.



We have now to draw in the top of the thread upon the curved surface of the half pattern. For this purpose we take a piece of stiff card or other flexible material (see Fig. 214), we wrap it around the pattern and fix it temporarily by tacks, trim off the edges true to the pattern, and mark upon the edges of the card the position of the tops of the thread upon each side; we remove the card and spread it out on a flat surface, join the points marked on the edges, as in Fig. 215, replace the card exactly as before upon the pattern, and with a fine scriber we prick through the lines. The cutting out is commenced by sawing, keeping of course well within the lines; and it is facilitated by attaching a stop to the saw, so as to insure cutting at all parts nearly to the exact depth. This stop is a simple strip of wood and may be clamped to the saw, though it is much more convenient to have a couple of holes in the saw blade for the passage of screws. For finishing, a pair of templates, Fig. 215, right and left, will be found useful; and finally the work should be verified and slight imperfections corrected by the use of a form taking in three spaces, as shown in Fig. 216. In drawing the lines on the card, we must consider whether it is a right or left handed worm that we desire. In the engravings, the full lines are those suitable for a right, and the dotted lines for a left handed thread. Having completed one half of the pattern, place the two halves together; and trace off the half that is uncut, using again the card template for drawing the lines on the curved surface. The cutting out will be the same as before.

Fig. 215

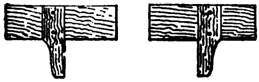
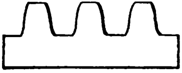
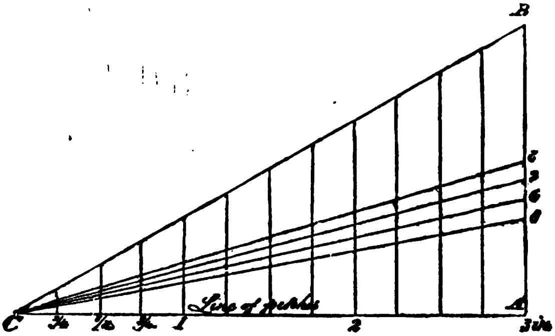


Fig. 216.



Another and very quick method of making a worm pattern is to turn down the body of the pattern to the diameter of the bottom of the thread or worm, and to then turn up some rings whose bore must be the same in diameter as the bottom of the worm. Now, suppose we cut one of these rings in four quarters, and fasten one section to the body of the pattern, then put on the next section, not fair with the first but as much to one side as the pitch of the thread requires, and continuing this process the thread may be fastened to the body. It is obvious, however, that the thickness of the washers must be greater than the thickness of the thread, but what their thickness requires to be depends on how many sections it is intended to cut them up into. It is best to so regulate the thickness, however, that the corner of each section on one side shall represent the exact pitch of the worm, so that the corners will act as a guide in cutting the thread.

The accompanying illustration (Fig. 217) represents a very serviceable article for those who may be called upon to lay out gearing. It is not new to the mechanical world, but as the author never happened to meet with but one man who actually had made himself a scale of this kind, he considers it will prove a novelty to a large class of pattern makers.



Draw the lines A B and A C at right angles to each other. Make A B equal to three inches; the line A C may be any convenient length, say six inches, as by observing this proportion the scale will be in addition a very useful set square, with the angles, at B and C, 60° and 30° respectively. Join B C; divide A B into 15 parts; from C draw lines to the fifth, sixth, seventh and eighth parts, as in the figure. Divide A C into as many parts as there are inches in A B, number the divisions, and erect perpendiculars to A B. These are for the even inch pitches. To make the scale serviceable for the fractional parts, divide and subdivide again, and erect a perpendicular at each division. This process in our figure is carried out to quarter inches. It may, however, be further extended, if desired; but inasmuch as it is so little trouble to draw a perpendicular at any time for any fractional pitch required, it may be preferred by some that the scale should not be overcrowded with lines.

Brass is probably the most suitable material, as it takes the lines readily, does not oxidize, and is sufficiently hard to stand considerable wear.

The method of using this scale will be clear from the following example. Let O, Fig. 218, be the center of a tooth wheel or pinion, and F P the pitch circle, which we will suppose already divided off, and that the pitch is one inch; on the perpendicular marked take with the compasses the distance up to line 5, and set this off outside the pitch for the tops of the teeth; on the same perpendicular take the distance up to line 6, and mark this inside the pitch circle for the roots of the teeth. With center O, and the points so found as distances, describe circles.

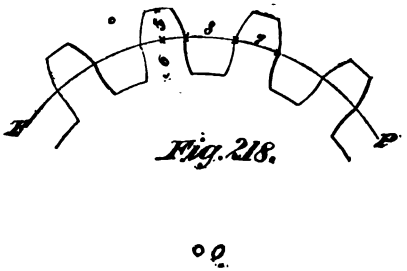


Fig. 218.

Make the thickness of the tooth equal to the distance on the scale up to line 7; the width of the space will then be equal to the distance up to line 8—all, of course, measured from the base line, A C.

Scales upon this principle may be made to accommodate any preferred proportions of the teeth of wheels.

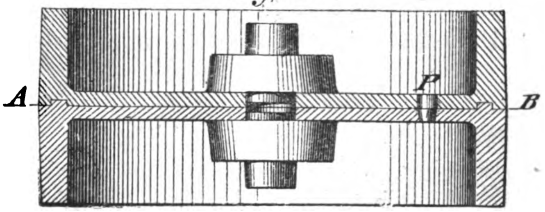
CHAPTER XV.

PATTERN FOR SECTION MOLDING.

For the sake of durability, patterns for pulleys are generally made of cast iron. For convenience in molding it is usual to make them in halves, as shown in Fig. 220, A B being the line of division. The hubs are of wood, as they frequently have to be changed to suit different sizes of shafts.

We may commence by building up a wooden pattern for half of the rim, making it of such a size as to allow for its being turned by the machinist after being cast. Two castings having been taken from this pattern, they are bored and turned to equal dimensions, the proper draught for molding being given in the process. A slight projection is turned upon one half, fitting into a recess on the other, as shown at B. When placed together, the two halves form the whole rim. The cast iron arms may be made either the full thickness or in halves. If made the full thickness, they will be fixed to one of the half rims. As half the thickness of the arms is made to project beyond the half rim, it will form a guide to keep the two rims central, so that in this case the projection, shown at B, need not be

Fig. 220.

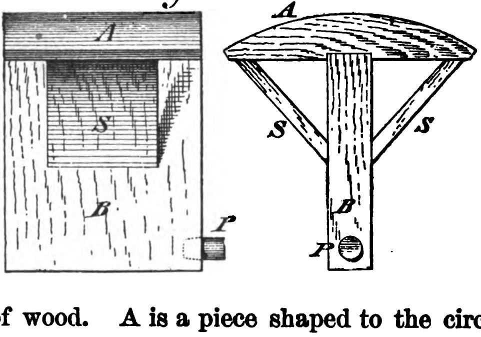


made. The arms are fitted to the ring by turning, and at the same time a hole is bored through the center to form a guide for the hub, as shown at P in the cut. When the arms are cast in two halves, and a half fitted in each rim; the pattern is easier to mold, as a level parting is secured. The rims must not only be kept central but be prevented from turning one on the other; hence the necessity for the hole to contain a pin, as shown at P. For convenience in drawing the pattern out of the sand, a couple of holes may be bored and tapped three eighths or half an inch, or larger if thought necessary, near the rim, diametrically opposite each other.

Occasions often occur when it is inexpedient to go to the expense of a pattern for making a pulley, especially if the pulley be large and only one or two castings required. In this case we may make use of the following contrivance, though it must not be expected that as well shaped castings can be made with it as from a finished pattern.

Fig. 221 illustrates by two views the apparatus as made wholly of wood. A is a piece shaped to the circle of the pulley. It is supposed to be large enough to extend at least about a sixth of its circumference; the depth of A is equal to the width of the rim. B forms a connection

Fig. 221.



between it and the center, where the print, P, is fastened. S S are simply braces to stiffen the frame, the use of which will presently be described.

A core box must now be made, embracing a section of the interior of the pulley. If the pulley is to have six arms, the core box will take up a sixth of the interior; if four arms, a fourth. We will suppose the pulley is to have six arms. The core is made as shown in Fig. 222. A B represents the arm of the pulley passing through the center of the box; from C to D is exactly a sixth part of the inner circumference of the rim. A sixth part of the hub is fixed in the other corner. The piece C D is loose at the joints, as it is necessary to take it off to get out the core. The arm also is loose. When the core is made in this box, the arm A B is first pulled out; then the piece C D is removed, and afterward the other pieces. The hollows around the ends of the arms may easily be formed by the core maker, or they may be formed in the box, as seen in Fig. 222. The hollow or fillet at the end of the arm near the center must be worked out solid with the arm itself, while that which is at the circumference is worked in a

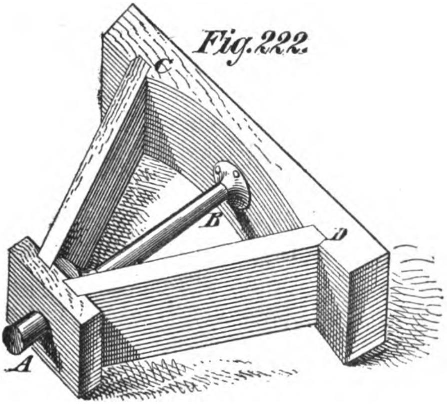


Fig. 222.

piece fixed to C D, the arm being diminished so as to center this piece without making a feather edge. A plain straight arm, oval in section, is the cheapest and most convenient for pulleys made in this way. It may, however, be curved like the arc of a circle, but not made S-formed, as it could not then be drawn out from the solid core.

The molder, having prepared a level bed, places upon it the frame, Fig. 221, allowing the print to impress itself in the sand; a weight is then placed upon the frame to keep it in position while the sand is piled around the curve and made level at the full height of the same. The frame is then shifted, and the sand molded in again. This process is repeated until the circle of the pulley is finished. Into the mold so prepared must now be placed six cores, made in the box described in Fig. 222, and also the core to make the hole for the shaft. The whole is then covered with a level cope, and prepared for the casting.

CHAPTER XVI.

COGGING.

The term cogging is applied by pattern makers and wheelwrights to the process of furnishing wooden teeth to iron wheels, in the rim face of which are cast mortises to receive the wooden cogs. The term cog is applied to the piece of wood out of which the tooth is formed. This includes the shank fitting into the mortise, together with the tooth projecting from the face of the wheel. The term tooth denotes the part forming the tooth independently of the part fitting into the mortise.

The object of using cogged wheels is to avoid the jar and noise incidental to the use of large cast gear wheels, which it is found impracticable to cast true. If the wheel is cast from a wooden pattern, this pattern is liable to warp. Furthermore, the rapping of the pattern in the mold tends somewhat to destroy the truth of the mold. Even if these elements of error are eliminated in making the mold by using a molding machine, the unequal shrinkage of the casting induces untruth. After a gear wheel is cast, the face is then to be turned true. While in the lathe a circle may be made for the bottom of the teeth, and another for the pitch line. Other circles may be made as are deemed necessary as guides for adjusting the instrument used to form the outlines of the teeth. The wheel may be marked off as carefully as can be, and the teeth, after marking, may be chipped and filed to the lines; but it is not found in ordinary practice that by any such means a degree of truth, sufficient to avoid jar and noise, is attainable. This is especially the case with large wheels, and cogging is resorted to. It is usual to cog the large wheel of a pair that run together, and to make the wood teeth thicker across the pitch line than the iron one. If two cast wheels are made to run together, there is usually given a certain amount of clearance between the spaces and the teeth; whereas, when a cogged wheel is employed, this clearance is dispensed with, and back lash is avoided. The woods generally used for cogging are hornbeam, hickory, buttonwood or sycamore, maple, and locust. The blocks for the cogs should be cut out and kept, so as to thoroughly season before being used. There should, when there is likely to be a demand for them, always be kept a spare set of cogs, so that they will be ready for use, well seasoned and less liable to shrink, and thus come loose in the mortises.

When the cast wheel arrives from the foundry, it is taken to the machine shop, bored and turned across the face. The mortises receive a little attention, burrs and sprue fins are removed, the rough places leveled, etc. If it should be found that any of the mortises are "blind," that is, stopped by the arms of the wheel, as shown at A, Fig. 223, a circumstance which is avoided as much as possible in the designing of the wheel, a small hole must be made through the rim to admit of the passage of a wire or screw. The

Fig. 223.

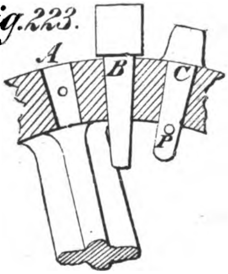
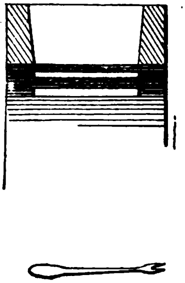


Fig. 224.



first step taken toward getting out the wood teeth is to obtain the exact size and shape of the mortises. For this purpose, if the wheel is a spur, we must cut out two pieces of thin wood, as templates to fit the mortise, one representing the length of the mortise, as in Fig. 224, and the other its width. The templates must be tried in several holes, so as to insure their being the correct size. *a b c d*, Figs. 225 and 226, represent one of these templates. From it we get the size of the rough cogs. Add above *b c* the height of the finished tooth, and from a quarter to half an inch more, according to the size of the wheel, to allow for turning off. Make a good allowance in this direction, as also at the other end of the piece, for the wood may be bruised by the hammer in driving the cogs in and out. The size of the cog is shown at *c f g h*, the length *f g* being that of the finished tooth, and not less than ⅛ inch allowed on each side for turning. To obtain the thickness, take that of the finished tooth, shown at C, Fig. 223, at the thickest part, and allow about ⅛ inch of a side for trimming.

Fig. 226.

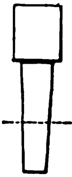
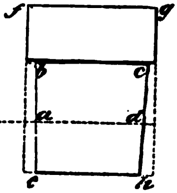


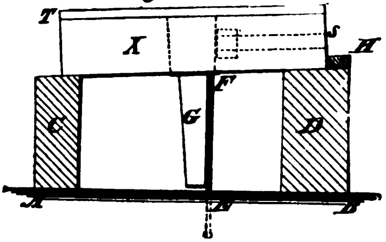
Fig. 225.



Having now the full size and thickness, cut out the number of cogs required, with three or four spare ones, as some may be split or possess some defect. To avoid damaging the teeth, a broad, flat-faced, heavy hand-hammer should be used to drive them with.

It is taken for granted that a circular saw bench is accessible, for without this cogging is made with difficulty. Have the saw in good order, and mount upon it a simple contrivance for shanking the cogs. It is composed of a box and two guides. These are illustrated in Figs. 227, 228, and 230, the parts throughout being marked with the same letters.

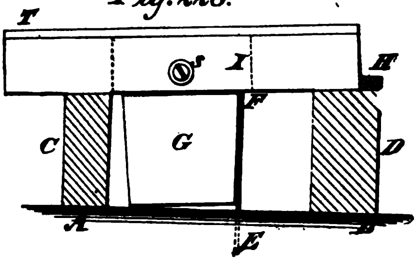
Fig. 227.



Make A C perpendicular with E F. Let E F be the height the saw stands above the table, which should be a little higher than the length of the shank of the cog. To the line E F apply the form or template, *a b c d*, of the width of the shank. Produce the top line of this form, and it is the top of the guides. Make the guide C at such a distance from the saw as to admit of the passage of the cogs the widest way. Make a box composed of two pieces, one piece being of sufficient thickness to take in the whole rough tooth of a cog in a mortise cut through the center of it, as indicated by the dotted lines in Figs. 231 and 232, and shown in full in Fig. 234. The thin piece T forms a backing to stop the cog in the mortise; it also, by being placed with the grain in an opposite direction to that of the box and screwed firmly, adds much to the strength of the box, and enables it to resist the strain of the binding screw S, by which the cogs are held while being sawed. Having the thickness of the box, lay it off upon the opposite side of E F, and draw the guide D; if, as at G, in Fig. 234, the size of the top of the shank be laid down, then the distance from it to the sides and ends of the box must be equal to E F, the height of the saw above the table. Having the size of the box, we can now mark the position of the guide H.

Eight movements with the box over the saw shanks the cog; two movements, as in Fig. 231, make slits through the width of the stuff and bring it to the right thickness; at Fig. 232, two movements, with the box held in the direction shown, bring the shank to the width. The box is now to be held with one of its edges on the table and passed between the guide, D, and the saw. It is to be passed through four times. A slab is detached each time.

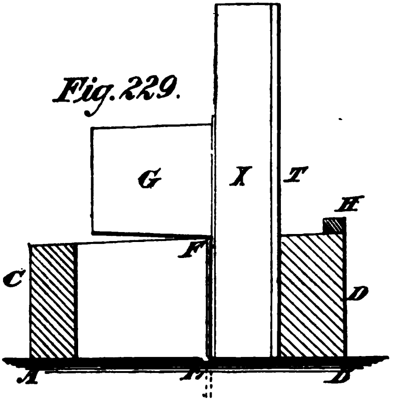
Fig. 228.



Figs. 229 and 230 illustrate two of these positions; and after turning the box upside down, the other two movements may be performed.

Having now completely shanked one cog, it must be compared with the templates and tried in the mortises.

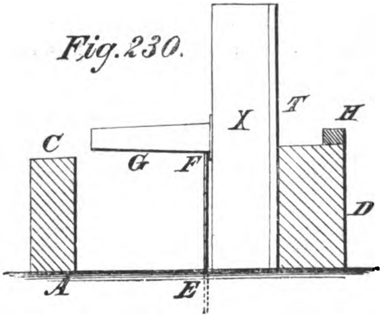
Fig. 229.



Care and patience at this time may save hours of labor in fitting. Proceed now to fit the cogs to the mortises, as at B, Fig. 223, driving them tightly, and leaving them with their shoulders, say, $\frac{1}{8}$ inch above the rim at the widest part. Use raw linseed oil to lubricate the surfaces while driving. All the cogs being now driven into their places, take a little instrument, shown in Fig. 224, called a fork scriber, and with this trace a line upon the shoulder of each cog by allowing one prong to travel along the turned face of the wheel while the other is pressed against the wood. The shanks of the cogs must also be marked with a common scriber where they project through on the under side of the rim.

Number all the cogs with a pencil, and number two of the mortises with a center punch or stamp, to show the direction of the numbering. Now drive out all the cogs and "shoulder" them, that is, dress the shoulders to the fork-scribe line, so that, when driven in, the shoulders will fit the face of the wheel. This being done, mark a mark on the shank; into this mark on both edges of the cog insert the fork scriber, and scribe a line parallel to the first but nearer up to the shoulder. This line shows where the under side of the rim will come when the cog is next driven in, for of course it will be driven just as much further as the distance between the two points of the fork scriber. In Fig. 223 observe the pin, P, the top of which lies against the rim; so in finding the center of the hole for the pin, we must place it nearly one half the diameter of the wire below the fork-scribe line. Make this nearly so as to have a little draw on the cog, and insure that the wire pin shall touch the rim. Then when the cogs shrink and become

Fig. 230.



loose in their mortises, as they often will, the pins will at least keep the shoulders in contact with the rim. Cogs in blind mortises are made to fit at the first drive and not removed, unless from some oversight it is inevitable. Carefully examine the hole and remove lumps or cut away the wood to escape them, and gage the size and depth of the hole. Do this to avoid the unpleasantness of having to draw the cog when once driven in.

The cogs may now be bored for the pin. This is most rapidly performed by running a boring bit in the lathe. The ordinary pin bit will do, but let it be so pointed as not to run away from the center mark made with a center punch. It should be lubricated with tallow or beeswax very frequently, or the temper will be drawn, because the material is so hard and the speed so high. It takes too much time to run the lathe mandrel back and forth by means of its screw; therefore, to remove the cap and wheel, fit a wooden knob or handle on the end of the screw and work the mandrel by hand. This will be clearly understood by turning the attention to Fig. 233. R is the running head with bit held by a chuck G, the cog T, tail-

Fig. 231.

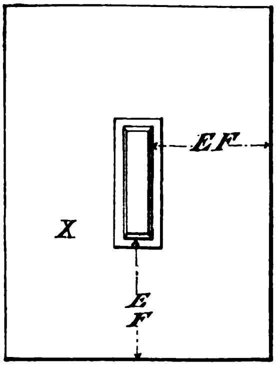
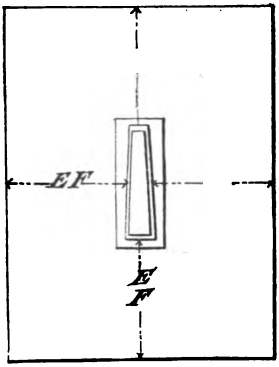


Fig. 232.



stock W, the knob of wood. This method bores the cogs rapidly and straight. The cog when bored half way may be reversed and the rest of the boring completed from the other side.

The next process is to saw the shanks off to an equal length, measured from the shoulders which have been dressed. In Fig. 234, S is the circular saw, F a guide strip, B a planed board, H a handle, T a stop. The cog G is shown with its shoulders resting against the edge of the board and its side against the stop. In this position it is held firmly by the left hand, the right hand seizes the handle and pushes toward the saw. A second stop is shown at O; it is fixed to the table to prevent the board by any inadvertence from being pushed too far. The ends of the shanks may now be rounded at the corners, or chamfered to give them a presentable appearance, and the cogs are ready to be again driven into the wheel. A mixture of white lead and boiled linseed oil is to be made, of the consistence of thick paint. This, with a piece of stick or brush, is applied to that part of the shank which remains in the rim. Each cog is then driven into the mortise, to which it was fitted, and which may be known by the number marked on it. Insert the pins—pieces of

Fig. 233.

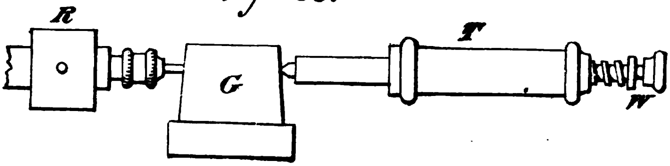
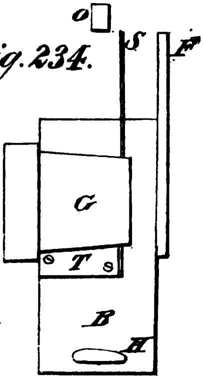


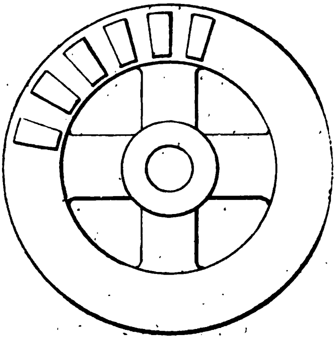
Fig. 234.



strong wire, pointed like a center punch; these are in length somewhat less than the rim is wide, but longer than the tooth. The wheel now goes to the turning shop, where the teeth are turned to the proper size and the pitch lines marked. Upon its return it is divided off, the outlines of the teeth drawn on both sides, and the excess of stuff removed with chisel and gouge. If it is possible to remove a portion with a good sharp handsaw, that may be done, as much time may be saved thereby. When the teeth are all formed, filed, and sandpapered, they may receive a few good soakings of raw linseed oil.

In bevel wheels the mortise is narrower at one end than at the other, as shown in Fig. 235. It follows that the shanks of the teeth must be made to fit; therefore an extra template must be made, so as to have one for each end of the mortise. The shape of the mortise, or in other words, the top of the shank and its size, is to be laid down as in Fig. 232, and the distance E F (the length of the top of the circular saw from the saw to the table) laid off on all sides, so that the box will assume a shape corresponding to that of the shank, the guides remaining the same. In this way the outer edges of the box form a gage to saw the cogs.

Fig. 235.



CHAPTER XVII.

MACHINE TOOLS FOR PATTERN MAKING.

Pattern making being a process for originating, it is obvious that the use of special tools in the same is out of the question; and there is at the present day no branch of woodworking in which power-driven tools or machines are so little used as in pattern making. In some pattern shops a lathe only is to be found; in a great many a lathe and jig-saw complete the complement. The lathes are in a majority of cases of simple, if not crude, construction, without any slide rest or self-acting feed motions — those shown in Figs. 45 and 55 being a fair representation. It must be conceded that from the desultory nature of pattern work and the fineness of finish required, hand work possesses many advantages, because in so many cases the work can be done by hand in about as much time as it would take to set a machine for the purpose. Furthermore, a hand plane can be sharpened on an oilstone in less time than it would take to stop a machine and take the planing cutter out. A pattern, when commenced, is worked upon by the workman or workmen until finished; and in any case each man does his own marking out, sawing, planing, boring, turning, etc.; and as each job must be, in the main, done in certain order, no part of his work can well—as a general rule—wait until a machine is unoccupied. Notwithstanding all this, however, there is no doubt that much work is done by hand that could be advantageously done in a machine, providing the latter does not occupy too much shop space, is not too heavy, is designed to perform several operations, and to be set for either of them readily and easily. As an example, core boxes and the segments for building up cylinders, etc., may be noted. A well constructed lathe device would bore a core box in a fraction of the time it requires by hand. A pattern maker's lathe having a friction straight and cross feed, and very light parts, would be a desirable tool, because of the facility with which facing up work and cutting out core boxes could be done. In facing up work, a large porportion of the time is spent in testing the straightness of the face. Core boxes could be bored out rapidly by fastening them to the light lathe saddle by a handy fixture designed for the purpose—the cutter being adjustable in a bar revolved between the lathe centers.

Of the few power tools or machines designed for pattern makers' use, a few of noteworthy examples are shown in the following engravings:

In Fig. 236 is shown a pattern maker's face lathe. The hand rest, it will be noted, is supported by an arm pivoted at one end, and supported by a leg at the other end, so that it can be adjusted to suit the work.

The reason for making the cone pulley of wood is, that its momentum when in motion being less than if of iron, it will stop and start more quickly; and this is a valuable consideration, when the lathe requires to be so often stopped and started, to try the work. The box frame is provided to prevent the excessive vibration to which lathes, supported upon legs, are subject under high speed.

In Fig. 237 is shown a smaller face lathe for turning hubs, bosses, core prints, and similar work, than can be done without the use of a back center.

In Fig. 238 is represented a lathe head and tailstock for mounting on either wooden or iron shears, as may be preferred. Iron shears keep more true, and the tailstock is more easily moved and kept in line or set over, as the case may be; the only objection to them being that they are apt to damage the edges of tools carelessly laid down; and wood may be made of large proportions, to avoid tremor where lathe shears and legs are used, as in this class of lathe.

It will be noted that each end of the cone spindle is provided with a face plate. The extra one is for use upon

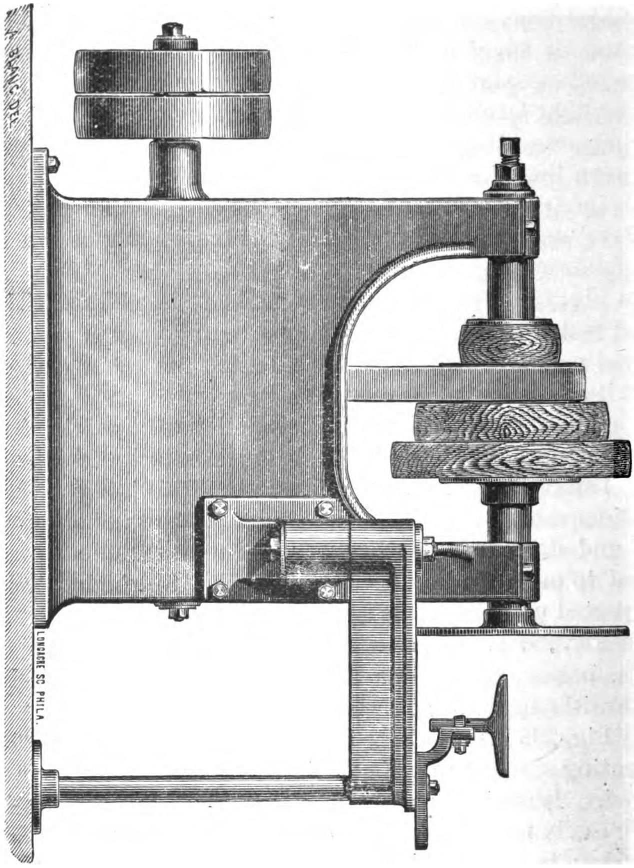


Fig. 236.

work too large to go between the lathe centers; in which case a movable hand rest — after the style shown in Fig.

47—becomes necessary. This provision is very handy, but is not so good as the large face lathe shown in Fig. 236.

Fig. 237.

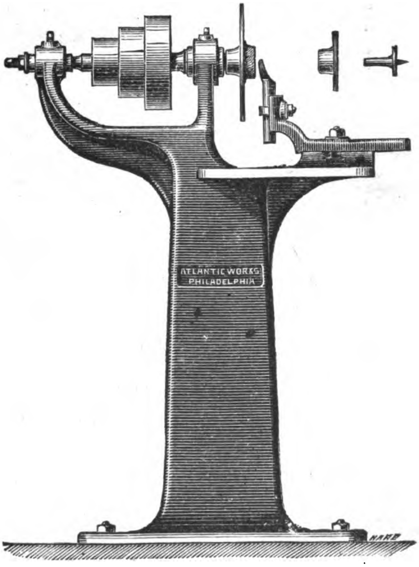
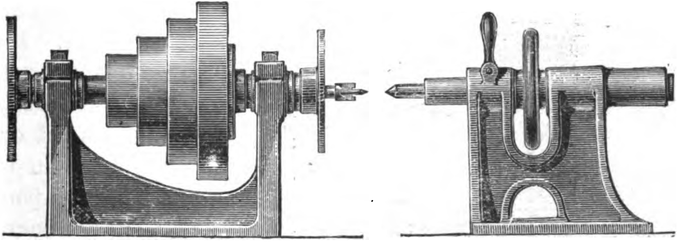


Fig. 238.



Next to a lathe, a jig saw is the power tool most commonly found in a pattern shop. It is indeed a very useful tool to the pattern maker, notwithstanding the noise and jar that usually attends its use. Its small expense and lightness, as compared to a band saw, are no doubt the considerations which cause it to be preferred, because the band saw is an infinitely superior machine, except it be in cases where an area surrounded by solid wood requires to be cut out, in which case the jig saw can be detached, passed through the work, and attached again — thus performing a duty peculiar to itself. In the jig saw, shown in Figs. 239 and 240, the table is planed true and pivoted, so as to cant over, for sawing bevels, or to give the pattern the necessary draught. The crank is provided with a conical schiele bearing at the front, adjusted by nuts at the end of the shaft. To stop the saw instantly, a friction brake is provided, and the sliding head or stock is adjustable in a long planed bearing upon the front of the column. The top guides are adjustable vertically, to suit different lengths of saws, and pivoted to regulate the

Fig. 239.

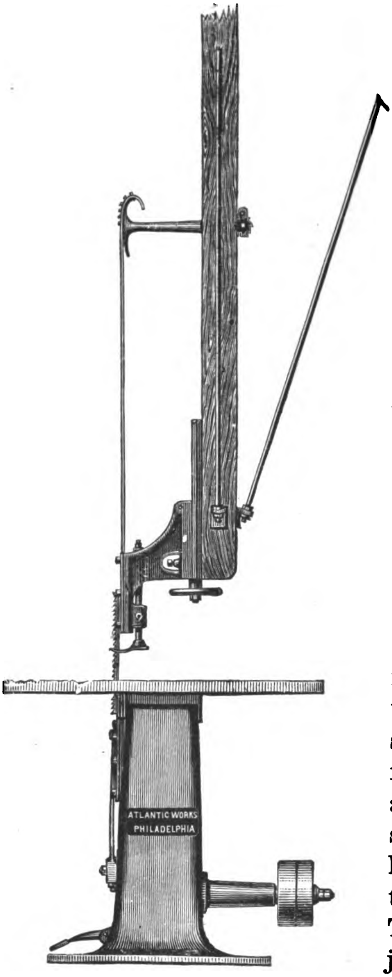
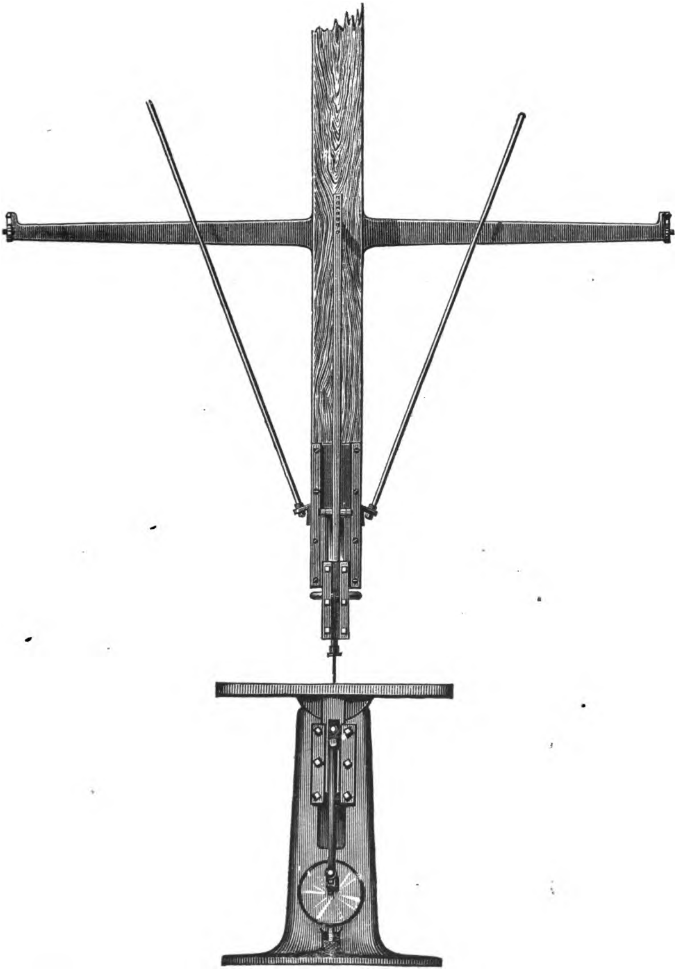


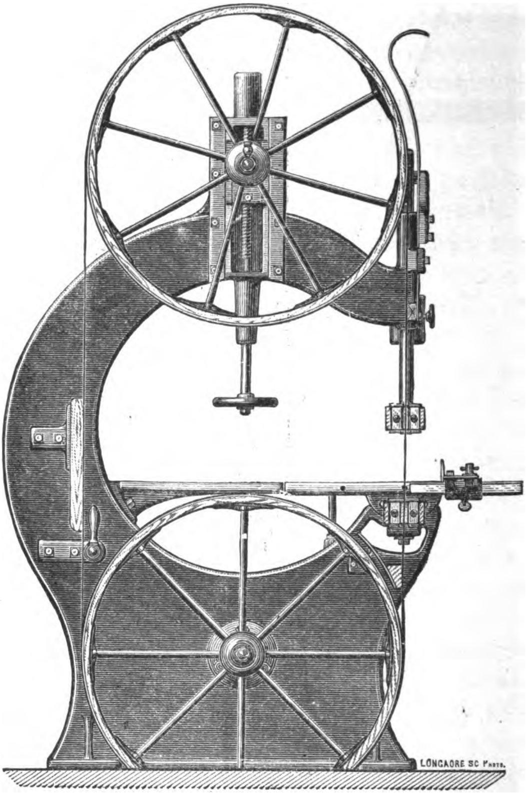
Fig. 240.



amount of rake given to the saw. The machine is also provided with a rotary fan, to remove the sawdust from the lines upon the work, and keep the latter visible.

The band sawing machine, shown in Fig. 241, is a very valuable machine for pattern making, because it will perform its duty with great truth as well as great rapidity,

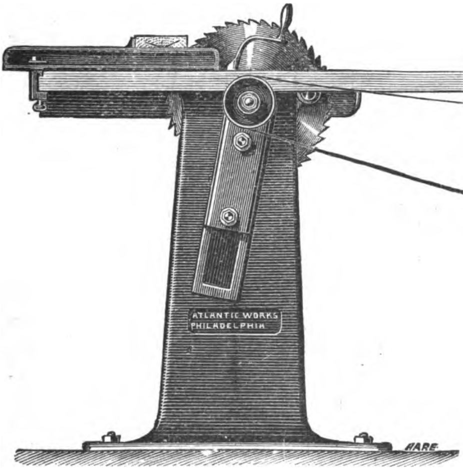
Fig. 241.



answering also the whole purpose of a circular saw, and very nearly the whole purpose of a jig saw. Among these qualifications, however, that of cutting true and exact to line is the most valuable, especially in the case of the teeth for wheels, segments, etc. The table is made adjustable for cutting bevels or draught.

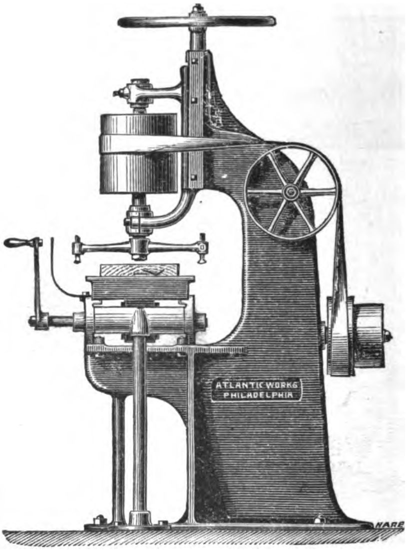
The circular saw, as used in pattern making, is mainly applied to roughing-out purposes. More stuff being left for finishing by hand, than would be the case were the work sawn with a band or a jig saw. The circular is a very useful saw, however, especially for roughing out rabbets and similar work. The table for pattern maker's use should adjust to saw at a bevel, and should rise and fall adjustably at one end, so that the saw may project more or less above the surface of the table; the height of the top of the saw, from the table surface vertically beneath it, regulating the depth of the groove the saw will cut. The same saw being used for slitting and cross-cutting purposes, the teeth are filed slightly pointed, and thus answer both purposes. The circular saw, shown in Fig. 242, is designed for pattern maker's use; the gage being operated by a screw operated by the handle shown.

Fig. 242.



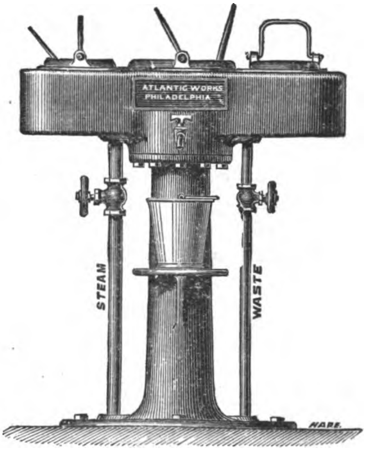
Roller feeding planing machines are not properly adapted for pattern making, because the pressure of the roller springs the work out of true. They may, it is true, be used upon work too thin to be held in other planers, but there being in any case no assurance of truth (that great desideratum for pattern makers) their employment, even for thin work, is not advisable. A traverse planing machine, however, is a very useful tool, especially upon segment work; hence such a machine is shown in Fig. 243. The frame is boxed, to secure rigidity with compactness and lightness. The feed is a hand one, as is preferred by all pattern makers, because it admits of rapid manipulation. The framing being open at the front, gives easy access to the cutters, and admits work of greater width.

Fig. 243.



In every pattern shop hot glue is a primary necessity, and steam is by all means the best medium of keeping the same heated ready for use. In Fig. 244 is shown a steam glue heater; the outer casing containing the water, there being a glue pot on each side of the upper face, and a pot for hot water in the center. In the absence of steam, the ordinary glue pot, heated by gas or a spirit lamp, is employed.

Fig. 244



The glue used in pattern making must be of the best quality, well boiled, and applied properly hot; because, notwithstanding the varnish, patterns are affected by the moisture of the molding-sand, and from rapping the pattern to loosen it in the mold. Defective gluing — or in fact any but the best executed gluing — will rapidly show itself, and impair the value of the pattern.

CHAPTER XVIII.

SHRINKAGE IN CASTINGS.

To allow for the shrinkage in castings, the pattern is not infrequently made in form and size to meet the requirements of any known case. Suppose, for example, that the surface of a large casting is found to be hollow, then that surface upon the pattern will be made sufficiently rounding to allow for the shrinkage, thus giving a casting with the desired flat surface. In large bodies of metal the shrinkage is always sufficient to demand an allowance therefor by the pattern maker; and it always takes place in the largest mass of the metal. The directions of this shrinkage are thus given for particular forms by Mr. ALFRED C. WATKINS:

SOLID CYLINDERS.

In the case of a shaft, or other solid cylinder, it will be noticed that the surface of the casting at the ends will be slightly depressed. This is occasioned by the surface of the cylinder being cooled by the walls of the mold first, and setting, while the central portion yet remains fluid or soft. In a few moments more the central portion cools, and in shrinking draws in the ends of the cylinder, the outer crust acting as a prop or stay to the atoms of metal adjacent to it. If this theory be correct, the depression should take the form of an inverted cone, owing to the gradual checking of the shrinkage as it approaches the outer crust. In practice this will be found the case—the obtuseness of the angle being greater or less, according to the nature of the iron to shrink.

GLOBES.

In the case of solid globular castings, the heart or central point within will usually be found hollow or porous, owing to the following causes: The walls of the mold cooling off the outer surface, causes it to set immediately; the interior, cooling from the exterior inward, endeavors to shrink away from the outer crust, which resists its so doing; hence, the interior is kept to a greater diameter than is natural, and there being but so much metal in the entire mass, the atoms are drawn away from the central point toward all directions, to supply the demand made by the metal in shrinking.

DISKS.

In the case of flat round disks or plates, they will usually be found hollow on the top side, although in some cases the hollow is on the bottom side. This is owing to the following causes: The top and bottom faces, together with the outside edge, become set first through contact with the mold, leaving the center yet soft. When the center shrinks a severe strain is put on the plate by an effort to reduce its diameter, which the outer edge resists. Now, if the cop be thin, the heat will radiate rapidly in that direction, causing the outer or top side to set first; the under side, setting later, will drag the top side over with it, causing it to round up on top and dish in the bottom. Or if the pattern be not perfectly true in every direction, the strains first spoken of will cause any curved portion to become more exaggerated. If the pattern be perfectly true, cop and drag of the same thickness, and both rammed evenly, there is no reason why the plate should not come out perfectly true, the strains being all self-contained in the same plane and balanced. If the plate, however, have an ogee molding projecting downward around the edge, it will likely be depressed on the top surface when cast. This is due to all the surfaces being set alike and at the same instant, excepting the metal within the corners, which, containing the most metal in a mass, will shrink last of all. When this does shrink, its tendency is to pull over the top side of the molding toward the plate, which being soft, although set, will be forced downward at the edges, giving a chance for the strains within the plate, as above described, to aid in the distortion.

ROUND AND SQUARE BARS.

These strains are similar in both, and are already treated of under solid cylinders. There is another feature, not before spoken of, which is rather curious. If two bars of the same dimensions and mixture of iron be heated to the same temperature, the one allowed to cool in the mold, the other plunged while hot into water, the latter will be found to have shrunk the most. This is due to the particles about the surface having been enabled, by the softness of the interior metal, to get closer to each other than they could have done if the material had cooled slowly.

RECTANGULAR TUBES.

These are usually cast with a core, which has a tendency to retain the shape of the casting; still the flat sides will show a tendency to bulge up slightly at the middle. This is due to much of the same causes—the outer surface is cooled instantly by the wall of the mold, and is set; the inner surface is not cooled quite so rapidly, owing to the core being of harder material, and not so good a conductor of heat. When this does cool it will pull inward the outer skin of the casting, forming a slight curve; each side acting for itself, will produce the same effects.

GUTTER, OR U-SHAPED CASTINGS.

These are usually made thinner at the edges than at the middle, because the pattern has been made with draught. When castings of this shape are taken from the mold, they will be found rounded over in the direction of their length, the legs being on the curved side. This is explained by the mold cooling and setting the legs first; then when the back or round shrinks, it pulls upward the two ends of the casting.

WEDGE-SHAPED CASTINGS.

In parallel castings of any length, having a cross section similar to a wedge—or similar to a "knife" in paper-mill work—the thick side will invariably be found concave and the thin edge curved. This is due to the same causes as explained above. The thin edge is set as soon as cast; the thick edge, cooling later, shrinks and draws the ends of the casting upward, and with them the thin edge, which acts as a pillar to resist further shrinkage.

RIBS ON PLATES.

All ribs have a tendency to curve a plate, if they be thicker or of the same thickness as the plate, owing to the fact that whatever shrinkage strain they possess is below the general plane of the shrinkage of the plate itself. If the ribs be thinner than the plate, they will cool first; and by resisting the shrinkage of the bottom of the plate, cause it to curve upwards, or "dish" on top.

GENERAL LAWS REGARDING SHRINKAGES.

The most metal in a mass always shrinks last; hence if a casting be composed of irregular thickness, it will be liable to be broken by the forces contained within itself. It is, therefore, especially necessary that columns and castings supporting or resisting great pressures, should be so designed as to prevent this great error. Moldings on columns are often so badly designed with regard to this matter, that the columns are excessively weak where they should be the strongest. As a rule, moldings should seldom be cast on a column, but rather bolted on. Much of the irregularity of flat castings and those of irregular shapes, could be remedied by a proper attention to cooling the castings while in the mold. To be sure, this is done to a certain extent, though few molders know why they do so. They know that by removing the sand from a particular casting, it will straighten in the shrinking. This is but the result of experience, not of thought, or any attempt to know why they so act. It is useful to know, also, that all shrinkage takes place while the casting is changing from a red to a black heat.

SHRINKAGE OF CASTINGS.

In locomotive cylinders	$\frac{1}{16}$	inch	in a foot.
In pipes	$\frac{1}{8}$	"	"
Girders, beams, etc	$\frac{1}{8}$	"	15 in.
Engine beams, connecting rods	$\frac{1}{8}$	"	16 in.
In large cylinders, say 70 in. diameter, 10 ft. stroke, the contraction of diameter is about	$\frac{3}{8}$	"	at top.
" " " "	$\frac{1}{2}$	"	at bottom
Shrinkage of length is	$\frac{1}{8}$	"	in 16 in.
In Thin brass	$\frac{1}{8}$	"	10 "
" Thick brass	$\frac{1}{8}$	"	12 "
" Zinc	$\frac{5}{16}$	"	12 "
" Lead	$\frac{5}{16}$	"	12 "
" Copper	$\frac{7}{32}$	"	12 "
" Tin	$\frac{9}{32}$	"	12 "

TO CALCULATE STRENGTH OF PIPES OR OTHER THIN CYLINDERS.

Rule:—Multiply the inside diameter of the pipe or cylinder in inches by the pressure in lbs. per square inch that is to act inside of it, and divide the product by 10,000. To this result add a sufficiency to insure a good casting, and to enable the pipe to stand handling; and this will give the total thickness.

Note:—The amount to be added varies with the diameter of the pipe.

On a 4″	pipe,	and under,		allow	$\frac{3}{16}$
6	"	over	4″	"	$\frac{1}{4}$
8	"	"	6	allow	$\frac{5}{16}$
12	"	"	8	"	$\frac{3}{8}$
30	"	"	12	"	$\frac{1}{2}$
48	"	"	30	"	$\frac{5}{8}$
70	"	"	48	"	$\frac{3}{4}$
100	"	"	70	"	$\frac{7}{8}$

Example:—What must be the thickness of a 25 inch cylinder for a steam engine, so that it may stand 60 lbs. per square inch?

$25 + 60 = 1500 \div 10000 = \frac{3}{20}$ or $\frac{5}{32}$ of an inch; add to this $\frac{3}{8} = \frac{1}{2}$ inch $+ \frac{1}{32}$. Add another $\frac{1}{8}$ for reboring.

MOLESWORTH'S RULE for calculating the necessary thickness of metal for cylinders or pipes, is as follows:

Rule:—Multiply the inside diameter of the pipe or cylinder by the pressure in lbs. per square inch it is to bear, and divide the product by 4000. The last product to be increased one half.

It is to be noted, however, that the rules for calculating the necessary thickness of a cylinder to withstand a given pressure, do not give the thickness that the pattern maker requires, because the number of times allowed for reboring the cylinder, its situation as to its being subjected to oxidation, and other similar considerations, have caused the existence in actual practice of greater thicknesses than those given by any of the rules; and in a general way specific kinds of cylinders are made to conform in thickness to that which practice has demonstrated to suit the requirements of the duty; this latter term including more than mere strength.

TO CALCULATE THE THICKNESS OF METAL FOR CYLINDERS FOR HYDRAULIC PRESSES.

Rule:—Multiply the constant number given below for the material of which the cylinder is to be made by the pressure in tons per square inch, and by half the internal diameter of the cylinder.

Example:—A 10-inch cylinder is to bear a pressure of 3 tons per square inch; what must be its thickness in cast iron?

CONSTANTS:	
Cast iron	·41
Gun metal	·22
Wrought iron	·14
Steel	·06

$\cdot 41 + 3 = 1{\cdot}23 + 5 = 6{\cdot}15$ or $6\frac{1}{4}$.

Example:—A steel cylinder of 5 inches internal diameter is to bear a pressure of 35 tons per square inch; what must be its thickness?

$0{\cdot}6 \times 35 = 2{\cdot}10 \times 2{\cdot}5 =$ *(Ans.)* $5{\cdot}25$, or $5\frac{1}{4}$ inches.

TO CALCULATE THE WEIGHT OF RIMS FOR FLY WHEELS.

Rule:—

$$W = \frac{2542FS}{n^2x^2f}$$

F = Constant force in pounds, or mean force on piston;
S = Stroke in feet;
W = Weight in pounds of fly wheel;
x = Radius of center of gyration in feet;
n = No. of revolutions per minute;
f = ·05.

Multiply the area of the cylinder by the mean pressure on the piston in lbs. per square inch, by the stroke in feet, and by 500, and divide by the product of the number of revolutions per minute, multiplied by the radius of the fly wheel, measured at the inside of the rim.

TABLES OF USEFUL INFORMATION.

MIXTURES OF METALS.

CASTINGS FOR	Copper.	Tin.	Zinc.	Lead.	Antim'y.	Bismuth.
Brass bearings	10	1½	½	....	....	....
Brass valves	9	1	¼	....	....	....
Bell metal	15	5	....	....	....	....
Yellow brass for castings	36	2½	17	2½	....	....
Gun metal	9	1	....	....	....	....
Fine solder	....	1	....	1	....	....
Plumber's solder	....	1	....	2	....	....
Solder for cast iron	....	2	....	1	....	....
Babbitt's metal	1	10	....	....	1	....
Metal to expand in cooling	....	....	....	9	2	1

Metal to heat and cool without loss of size or alteration of shape, must contain 9 parts of copper and 1 of aluminium.

MELTING POINTS OF METALS.

Cast iron	from 1900° to 2900° Fahr.
Antimony	812°
Lead	620°
Aluminium	1292°
Copper	1994°
Tin	442°
Zinc	773°

WEIGHT OF MATERIALS AND CASTINGS.

ESTIMATING WEIGHT OF CASTINGS FROM THE WEIGHT OF THE PATTERN.

In presenting a table wherefrom to estimate the weight of a casting from the weight of the pattern, it must be understood that the calculation is *only approximate;* and in all cases in which there are core prints or battens to sustain the pattern, or other extraneous parts which exist upon the pattern and not upon the casting, the weight of these parts must be estimated, or calculated, and deducted from the weight of the pattern.

A PATTERN WEIGHING 1 LB. AND CAST IN	WILL WEIGH WHEN CAST IN				
	Cast iron.	Zinc.	Copper.	Yellow brass	Gun metal.
	lbs.	lbs.	lbs.	lbs.	lbs.
Mahogany, Nassau......	10·7	10·4	12·8	12·2	12·5
“ Honduras ...	12·9	12·7	15·3	14·6	15·0
“ Spanish	8·5	8·2	10·1	9·7	9·9
Pine, Red	12·5	12·1	14·9	14·2	14·6
“ White............	16·7	16·1	19·8	19	19·5
“ Yellow	14·1	13·6	16·7	16	16·5

WEIGHT OF TIMBER.

WEIGHT OF	A cubic foot.	A cubic inch.	WEIGHT OF	A cubic foot.	A cubic inch.
	lbs.	lbs.		lbs.	lbs.
Ash	45	·026	Maple	42	·025
Beech	43	·025	Oak, Red American..	53	·03
Box	80	·046	Oak, White American	49	·028
Hornbeam	47	·027	Pine, Red	36	·021
Lignum-vitæ.........	83	·048	“ “	41	·024
Mahogany, Nassau ...	42	·024	“ White	27	·015
“ Honduras.	35	·02	“ “	34	·02
“ Spanish...	53	·031	“ Yellow.........	32	·018

WEIGHT OF CAST METALS.

Metal.	Specific gravity.	Weight per cubic foot.	Weight per cubic inch.
		lbs.	lbs.
Aluminium....................	2·56	159·8	·096
Antimony	6·72	419·5	·242
Copper.........................	8·607	537·3	·31
Iron, from......................	7	437·	·252
“ to	7·6	474·4	·273
“ average	7·23	451·	·26
Lead...........................	11·36	708·5	·408
Steel...........................	8	499·	·288
Tin	7·291	455·1	·262
Zinc	7·	437·	·252
Gun Metal—10 copper, 1 tin...	8·561	534·42	·308
Babbitt metal	7·31	456·32	·263
Average composition (bearing), brass		524·88	·30375

TABLE

Of the Weight of Copper Bolts, from ¼ to 2⅛ in. Diameter, and 12 inches long.

Diameter.	Pounds.	Diameter.	Pounds.	Diameter.	Pounds.
¼	·189	13/16	1·998	1 and ⅜	5·723
5/16	·296	⅞	2·318	1 and 7/16	6·255
⅜	·425	15/16	2·661	1 and ½	6·811
7/16	·579	1	3·016	1 and 9/16	7·390
½	·757	1 and 1/16	3·417	1 and ⅝	7·933
9/16	·958	1 and ⅛	3·831	1 and ¾	9·270
⅝	1·182	1 and 3/16	4·269	1 and ⅞	10·642
11/16	1·431	1 and ¼	4·730	2	12·061
¾	1·703	1 and 5/16	5·214	2 and ⅛	13·668

TABLE

Of the Weight of a Lineal Foot of Cast Iron Pipes, in lbs., from 1 inch to 30 inches Bore.

Bore. Inches.	Thickness. Inches.	Weight. Pounds.	Bore. Inches.	Thickness. Inches.	Weight. Pounds.	Bore. Inches.	Thickness. Inches.	Weight. Pounds.
1	¼	3·06	3¾	½	20·90		⅞	63·18
	⅜	5·05		⅝	26·83	7	½	36·66
1¼	¼	3·67		¾	33·07		⅝	46·80
	⅜	6·	4	½	22·05		¾	56·96
1½	⅜	6·89		⅝	28·28		⅞	67·60
	½	9·80		¾	34·94		1	78·39
1¾	⅜	7·80	4¼	½	23·35	7½	½	39·22
	½	11·04		⅝	29·85		⅝	49·92
2	⅜	8·74		¾	36·73		¾	60·48
	½	12·28	4½	½	24·49		⅞	71·76
2¼	⅜	9·65		⅝	31·40		1	83·28
	½	13·48		¾	38·58	8	½	41·64
2½	⅜	10·57	4¾	½	25·70		⅝	52·68
	½	14·66		⅝	32·91		¾	64·27
	⅝	19·05		¾	40·43		⅞	76·12
2¾	⅜	11·54	5	½	26·94		1	88·20
	½	15·91		⅝	34·34	8½	½	44·11
	⅝	20·59		¾	42·28		⅝	56·16
3	⅜	12·28	5½	½	29·40		¾	68·
	½	17·15		⅝	37·44		⅞	80·50
	⅝	22·15		¾	45·94		1	93·28
	¾	27·56	6	½	31·82	9	½	46·50
3¼	½	18·40		⅝	40·56		⅝	58·92
	⅝	23·72		¾	49·60		¾	71·70
	¾	29·64		⅞	58·96		⅞	84·70
3½	½	19·66	6½	½	34·32		1	97·98
	⅝	25·27		⅝	43·68	9½	½	48 98
	¾	31·20		¾	53 30		⅝	62·02

* NOTE:—These weights do not include any allowance for spigot and faucet ends.

Bore.	Thickness.	Weight.	Bore.	Thickness.	Weight.	Bore.	Thickness.	Weight.
Inches.	Inches.	Pounds.	Inches.	Inches.	Pounds.	Inches.	Inches.	Pounds.
9½	¾	75·32	14	⅝	89·61	19	¾	145·20
	⅞	88·98		¾	108·46		⅞	170·47
	1	102·90		⅞	127·60		1	195·92
10	½	51·46		1	147·03	20	⅝	126·33
	⅝	65·08	14½	½	73·72		¾	152·53
	¾	78 99		⅝	92·66		⅞	179·02
	⅞	93·24		¾	112·10		1	205·80
	1	108·84		⅞	131 86	21	⅝	132·50
10½	½	53·88		1	151·92		¾	159·84
	⅝	68·14	15	½	75·96		⅞	187·60
	¾	82·68		⅝	95·72		1	215·52
	⅞	97·44		¾	115·78	22	⅝	138·60
	1	112·68		⅞	136·15		¾	167·24
11	½	56·34		1	156·82		⅞	196·46
	⅝	71·19	15½	½	78·40		1	225·38
	¾	86·40		⅝	98·78	23	⅝	144·77
	⅞	101·83		¾	119·48		¾	174·62
	1	117·60		⅞	140·40		⅞	204·78
11½	½	58·82		1	161·82		1	235·28
	⅝	74·28	16	½	80·87	24	⅝	150·85
	¾	90·06		⅝	101·82		¾	181·92
	⅞	106·14		¾	123·14		⅞	213·28
	1	122·62		⅞	144·76		1	245·08
12	½	61·26		1	166·60	25	⅝	156·97
	⅝	77·36	16½	½	83·30		¾	189·28
	¾	93·70		⅝	104·82		⅞	221·94
	⅞	110·48		¾	126·79		1	254·86
	1	127·42		⅞	149·02	26	¾	196·62
12½	½	63·70		1	171·60		⅞	230·56
	⅝	80·40	17	½	85·73		1	264·66
	¾	97·40		⅝	107·96	27	¾	204·04
	⅞	114·72		¾	130·48		⅞	239·08
	1	132·35		⅞	153·30		1	274·56
13	½	66·14		1	176·58	28	¾	211·32
	⅝	83·46	17½	½	88·23		⅞	247·62
	¾	101·08		⅝	111·06		1	284·28
	⅞	118·97		¾	134·16	29	¾	218·70
	1	137·28		⅞	157·59		⅞	256·20
13½	½	68·64		1	181·33		1	294·02
	⅝	86·55	18	⅝	114·10	30	¾	226·20
	¾	104·76		¾	137·84		⅞	264·79
	⅞	123·30		⅞	161·90		1	303·86
	1	142·16		1	186·24		1⅛	343·20
14	½	71·07	19	⅝	120·24			

The above table is found to be of great use in making out correct estimates of cast iron pipes. For instance, suppose it is required to know the weight of a range of pipes, 324 feet long, 8½ inches diameter of bore, and metal ⅝ of an inch thick. The table shows the weight of 1 foot of such pipe to be 56·16 lbs:

Then, $56·16 \times 324 = 18195·84$ lbs., or $9\frac{1}{10}$ tons, very nearly.

TABLE,

Showing the Weight of Solid Cylinders of Cast Iron, 12 inches long, in Avoirdupois Pounds.

Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.	Diameter in Inches.	Weight in lbs.
¾	1·394	2½	15·492	4½	50·193	8	158·638
⅞	1·897	2⅝	17·080	4¾	55·926	8½	179·087
1 in.	2·478	2¾	18·745	5	61·968	9	200·774
1⅛	3·137	2⅞	20·488	5¼	68·319	9½	223·704
1¼	3·873	3	22·308	5½	74·981	10	247·872
1⅜	4·686	3⅛	24·206	5¾	81·952	10½	273·278
1½	5·577	3¼	26·181	6	89·234	11	299·925
1⅝	6·545	3⅜	28·234	6¼	96·825	11½	327·811
1¾	7·591	3½	30·364	6½	104·726	12	356·935
1⅞	8·714	3⅝	32·572	6¾	112·936	13	418·903
2	9·915	3¾	34·857	7	121·457	14	485·830
2⅛	11·193	3⅞	37·219	7¼	130·287	15	557·712
2¼	12·548	4	39·660	7½	139·428	16	634·552
2⅜	13·981	4¼	44·771	7¾	148·878		

Note. Cubic inches of cast iron × ·263 = lbs. avoirdupois.
Circular inches of cast iron × ·2065 = lbs. avoirdupois.

TABLE,

Showing the Capacity and Weight of Cast Iron and Lead Balls, from 1 inch to 8½ Diameter.

Diam. inches.	Capacity in Cubic Inches.	Cast Iron Pounds.	Lead Pounds.	Diam. inches.	Capacity in Cubic Inches.	Cast Iron Pounds	Lead Pounds.
1	·523	·136	·215	5	65·450	17·063	26·843
1½	1·767	·461	·725	5½	87·114	22·721	35·729
2	1·189	1·092	1·718	6	113·097	29·484	46·385
2½	8·181	2·133	3·355	6½	143·793	37·453	58·976
3	14·137	3·685	5·798	7	179·594	46·820	73·659
3½	22·449	5·852	9·207	7½	220·893	57·587	90·598
4	33·510	8·736	13·744	8	268·082	69·889	109·552
4½	47·713	12·439	19·569	8½	321·555	83·840	131·883

TABLE,

Showing the Number of Nails and Spikes to the Pound, of Various Sizes, as manufactured at the Troy Iron and Nail Factory, N. Y.

Size of Nails.	No. to the lb.	Boat Spikes.	Diameter of Rod.	No. Spikes to the lb.	Ship Spikes.	Diameter of Rod.	No. Spikes to the lb.
3 penny	600	No. 4	¼	13	No. 4	5/16	8
4 "	360	" 5	5/16	8	" 5	⅜	6
6 "	200	" 6	⅜	5	" 6	⅜	5
8 "	110	" 7	½	4	" 7	½	3½
10 "	88				" 8	½	3
12 "	68				" 9	9/16	2
20 "	40				" 10	9/16	1½

WEIGHT OF A FOOT IN LENGTH OF FLAT CAST IRON.

Width of iron.	Thick, 1-4th inch.	Thick, 3-8th inch.	Thick, 1-2 inch.	Thick, 5-8th inch.	Thick, 3-4th inch.	Thick, 7-8th inch.	Thick, 1 inch.
Inches.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
2	1·56	2·34	3·12	3·90	4·68	5·46	6·25
2¼	1·75	2·63	3·51	4·39	5·27	6·15	7·03
2½	1·95	2·92	3·90	4·88	5·85	6·83	7·81
2¾	2·14	3·22	4·29	5·37	6·44	7·51	8·59
3	2·34	3·51	4·68	5·85	7·03	8·20	9·37
3¼	2·53	3·80	5·07	6·34	7·61	8·88	10·15
3½	2·73	4·10	5·46	6·83	8·20	9·57	10·93
3¾	2·93	4·39	5·85	7·32	8·78	10·25	11·71
4	3·12	4·68	6·25	7·81	9·37	10·93	12·50
4¼	3·32	4·97	6·64	8·30	9·96	11·62	13·28
4½	3·51	5·27	7·03	8·78	10·54	12·30	14·06
4¾	3·71	5·56	7·42	9·27	11·13	12·98	14·84
5	3·90	5·86	7·81	9·76	11·71	13·67	15·62
5¼	4·10	6·15	8·20	10·25	12·30	14·35	16·40
5½	4·29	6·44	8·59	10·74	12·89	15·03	17·18
5¾	4·49	6·73	8·98	11·23	13·46	15·72	17·96
6	4·68	7·03	9·37	11·71	14·06	16·40	18·75

TABLE

OF THE RELATIVE WEIGHT AND STRENGTH OF ROPES AND CHAINS.

Circumference of rope in	Weight per fathom in	Diameter of chain in	Weight per fathom in	Proof of strength in		Circumference of rope in	Weight per fathom in	Diameter of chain in	Weight per fathom in	Proof of strength in	
Inches.	lbs.	Inches.	lbs.	tons.	cwts.	Inches.	lbs.	Inches.	lbs.	tons.	cwts.
3½	2¾	5/16	5½	1	5½	10	23	7/8	43	10	0
4¼	4¾	3/8	8	1	16¼	10¾	28	15/16	49	11	11
5	5¾	7/16	10½	2	10	11½	30½	1	56	13	8
5¾	7	½	14	3	5½	12¼	36	1 1/16	63	14	18
6½	9¾	9/16	18	4	3½	13	39	1⅛	71	16	14
7	11¾	⅝	22	5	2	13¾	45	1 3/16	79	18	11
8	15	11/16	27	6	4½	14½	48½	1¼	87	20	8
8¾	19	¾	32	7	7	15¼	56	1 5/16	96	22	13
9½	21	13/16	37	8	13½	16	60	1⅜	106	24	18

TABLE

OF

THE WEIGHT, IN LBS.

Of a foot in length of Cast Iron.

Side of the square or diameter.	Square.	Hex'on.	Oct'gon.	Circle.	Side of the square or diameter.	Square.	Hex'on.	Oct'gon.	Circle.
inches.					inches.				
½	·781	·675	·650	·612	6½	132·031	114·271	109·948	103·696
¾	1·756	1·528	1·471	1·387	6¾	142·381	123·231	118·534	111·825
1	3·125	2·703	2·603	2·454	7	153·125	132·528	127·478	120·372
1¼	4·881	4·225	4·065	3·854	7¼	161·256	142·162	136·743	128·986
1½	7·031	6·085	5·856	5·521	7½	175·781	152·037	146·337	138·056
1¾	9·568	8·281	7·971	7·515	7¾	187·693	162·449	156·259	147·415
2	12·520	10·815	10·412	9·815	8	200·000	173·099	166·503	157·078
2¼	15·818	13·990	13·168	12·425	8¼	212·693	184·087	177·071	167·049
2½	19·531	16·900	16·256	15·337	8½	225·781	195·412	187·365	177·328
2¾	23·631	20·450	19·671	18·559	8¾	239·256	207·078	199·127	187·912
3	28·125	24·340	23·412	22·087	9	253·125	219·078	210·721	199·203
3¼	33·009	28·565	27·475	25·921	9¼	266·781	231·418	222·600	210·800
3½	38·281	33·131	31·818	30·065	9½	282·031	244·100	234·793	221·506
3¾	43·943	38·031	36·581	31·512	9¾	296·968	257·105	247·315	233·318
4	50·000	43·271	41·621	39·268	10	312·500	270·471	260·163	245·437
4¼	56·443	48·353	46·990	44·331	10¼	328·318	284·159	273·341	257·859
4½	63·281	54·768	52·681	49·700	10½	344·531	298·193	286·828	270·593
4¾	70·506	61·021	58·696	55·375	10¾	351·131	312·559	300·646	283·633
5	78·125	67·515	65·040	61·359	11	378·125	327·268	314·796	296·978
5¼	86·131	74·549	71·701	67·709	11¼	393·216	342·315	329·268	310·631
5½	94·531	81·815	78·696	74·243	11½	410·281	357·693	344·062	324·587
5¾	103·318	89·421	86·015	81·126	11¾	429·023	373·325	359·187	338·856
6	112·500	97·368	93·656	88·354	12	450·000	389·475	374·631	353·428
6¼	122·058	105·640	101·621	95·871					

TABLE

OF

THE WEIGHT OF A CUBIC FOOT OF VARIOUS SUBSTANCES,

In common use for Building.

	lbs.
Sand (solid)	**112·5**
" (loose)	**95**
Earth	**93·75**
Common soil	**124**
Strong soil	**127**
Clay	**120 to 135**
Clay and stone	**158**
Brick	**119**
Granite	**169**
Marble	**166 to 169**
Sand, 1 cubic yard,	**3037**
Common soil, 1 cubic yard,	**3429**

WEIGHT OF WIRE—PER LINEAL FOOT.

American Gage.	Size of each number.	Wrought Iron.	Steel.	Copper.	Brass.
Nos.	inch.	lbs.	lbs.	lbs.	lbs.
0000	.46000	.560740	.566030	.640513	.605176
000	.40964	.444683	.448879	.507946	.479908
00	.36480	.352659	.355986	.402830	.380666
0	.32495	.279665	.282303	.319451	.301816
1	.28930	.221789	.223891	.253342	.239353
2	.25763	.175888	.177548	.200911	.189818
3	.22942	.139480	.140796	.159323	.150522
4	.20431	.110616	.111660	.126353	.119376
5	.18194	.087720	.088548	.100200	.094666
6	.16202	.069565	.070221	.079462	.075075
7	.14428	.055165	.055685	.063013	.059545
8	.12849	.043751	.044164	.049976	.047219
9	.11443	.034699	.035026	.039636	.037437
10	.10189	.027512	.027772	.031426	.029687
11	.090742	.021820	.022026	.024924	.023549
12	.080808	.017304	.017468	.019766	.018676
13	.071961	.013722	.013851	.015674	.014809
14	.064084	.010886	.010989	.012435	.011746
15	.057068	.008631	.008712	.009859	.009315
16	.050820	.006845	.006909	.007819	.007587
17	.045257	.005427	.005478	.006199	.005857
18	.040303	.004304	.004344	.004916	.004645
19	.035390	.003413	.003445	.003899	.003684
20	.031961	.002708	.002734	.003094	.002920
21	.028462	.002147	.002167	.002452	.002317
22	.025347	.001703	.001719	.001945	.001838
23	.022571	.001350	.001363	.001542	.001457
24	.020100	.001071	.001081	.001223	.001155
25	.017900	.0008491	.0008571	.0009699	.0009163
26	.01594	.0006734	.0006797	.0007692	.0007267
27	.014195	.0005340	.0005391	.0006099	.0005763
28	.012641	.0004235	.0004275	.0004837	.0004570
29	.011257	.0003358	.0003389	.0003835	.0003624
30	.010025	.0002663	.0002688	.0003042	.0002874
31	.008928	.0002113	.0002132	.0002413	.0002280
32	.007950	.0001675	.0001691	.0001913	.0001808
23	.007080	.0001328	.0001341	.0001517	.0001434
34	.006304	.0001053	.0001063	.0001204	.0001137
35	.005614	.00008366	.00008445	.0000956	.00009015
36	.005000	.00006625	.00006687	.0000757	.0000715
37	.004453	.00005255	.00005304	.00006003	.00005671
38	.003965	.00004166	.00004205	.00004758	.00004496
39	.003531	.00003305	.00003336	.00003775	.00003566
40	.003144	.00002620	.00002644	.00002992	.00002827
FOOT…………………		485.87	490.45	554.988	524.16

The specific gravities to determine the weights, were taken and made by CHAS. H. HASWELL.

WEIGHT OF METAL PLATES—PER SQUARE FOOT.

American Gage,	Wrought Iron.	Steel.	Copper.	Brass.
Nos.	lbs.	lbs.	lbs.	lbs.
0000	17.25	17.48	20.838	19.688
000	15.3615	15.5663	18.5567	17.5326
00	13.68	13.8624	16.5254	15.6134
0	12.1823	12.3447	14.7162	13.904
1	10.8488	10.9934	13.1053	12.382
2	9.6611	9.7899	11.6706	11.0266
3	8.6033	8.7180	10.3927	9.8192
4	7.6616	7.7638	9.2552	8.7445
5	6.8228	6.9137	8.2419	7.787
6	6.0758	6.1568	7.3395	6.9345
7	5.4105	5.4826	6.5359	6.1752
8	4.8184	4.8826	5.8206	5.4994
9	4.2911	4.3483	5.1837	4.8976
10	3.8209	3.8718	4.6156	4.3609
11	3.4028	3.4482	4.1106	3.8838
12	3.0303	3.0707	3.6606	3.4586
13	2.9985	2.7345	3.2598	3.0799
14	2.4032	2.4352	2.9030	2.7428
15	2.1401	2.1686	2.5852	2.4425
16	1.9058	1.9312	2.3021	2.1751
17	1.6971	1.7198	2.0501	1.937
18	1.5114	1.5315	1.8257	1.725
19	1.3459	1.3638	1.6258	1.5361
20	1.1985	1.2145	1.4478	1.3679
21	1.0673	1.0816	1.2893	1.2182
22	.95051	.96319	1.1482	1.0849
23	.84641	.8577	1.0225	.96604
24	.75375	.7638	.91053	.86028
25	.67125	.6802	.81087	.76612
26	.59775	.60572	.72208	.68223
27	.53231	.53941	.64303	.60755
28	.47404	.48036	.57264	.54103
29	.42214	.42777	.50994	.48180
30	.37594	.38095	.45413	.42907
31	.3348	.33926	.40444	.38212
32	.29813	.3021	.36014	.34026
33	.2655	.26904	.32072	.30302
34	.2364	.23955	.28557	.26981
35	.21053	.21333	.25431	.24028
36	.1875	.19	.2265	.2140
37	.16699	.16921	.20172	.19059
38	.14869	.15067	.17961	.1697
39	.13241	.13418	.15995	.15113
40	.1179	.11947	.14242	.13456

TABLE

SHOWING THE WEIGHT OF WATER IN PIPES FOR VARIOUS DIAMETERS ONE FOOT IN LENGTH.

Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.	Diameter in Inches.	Weight in Pounds.
3	3	11½	45	20	136¼
3¼	3½	11¾	47	20½	143¼
3½	4¼	12	49	21	150¼
3¾	4¾	12¼	51	21½	157½
4	5½	12½	53¼	22	165
4¼	6¼	12¾	55½	22½	172½
4½	7	13	57½	23	180¼
4¾	7¾	13¼	59¾	23½	188¼
5	8½	13½	62¼	24	196¼
5¼	9¼	13¾	64½	24½	204½
5½	10¼	14	66¾	25	213
5¾	11¼	14¼	69¼	25½	221½
6	12¼	14½	71½	26	230½
6¼	13¼	14¾	74¼	26½	239½
6½	14½	15	76¾	27	248½
6¾	15½	15¼	79¼	27½	257¾
7	16¾	15½	82	28	267¼
7¼	18	15¾	84½	28½	276¾
7½	19¼	16	87¼	29	286½
7¾	20½	16¼	90	29½	296½
8	21¾	16½	92¼	30	306¾
8¼	23¼	16¾	95½	30½	317¼
8½	24½	17	98½	31	327½
8¾	26	17¼	101½	31½	338¼
9	27½	17½	104½	32	349
9¼	29¼	17¾	107½	32½	360
9½	30¾	18	110½	33	371¼
9¾	32½	18¼	113½	33½	382½
10	34	18½	116½	34	394
10¼	35½	18¾	119¾	34½	405¾
10½	37½	19	123	35	417½
10¾	39¼	19¼	126¼	35½	429½
11	41¼	19½	129½	36	441¾
11¼	43¼	19¾	132	....	....

UNITED STATES WEIGHTS AND MEASURES.

MEASURE OF LENGTH.

3 barleycorns - = 1 inch.
12 inches - - - = 1 foot.
3 feet - - - = 1 yard.
5½ yards or 16½ ft. = 1 rod or pole.
40 rods or 220 yds. = 1 furlong.
8 furlongs or 1760 yds. = 1 mile.
60 geo. miles = 1 degree.

Ropes and Cables.

6 feet = 1 fathom.
120 fathoms = 1 cable's length.

SPECIAL MEASURE OF LENGTH.

Land Measure.

7·92 inches - - - = 1 link.
100 links or 22 yards = 1 chain.
80 chains - - - = 1 mile.
60·121 miles - - - - = 1 geographical degree.

Nautical Measure.

1 nautical mile = 6082·66 feet.
3 miles = 1 league.
20 leagues = 1 degree.
360 degrees = the earth's circumference.

Note.—Bowditch gives 6120 feet in a sea mile, which, if taken as the length, will make the divisions 51 feet and 5 1-10 feet for the knot and fathom.

Pendulums.

6 points = 1 line.
12 lines = 1 inch.

CLOTH MEASURE.

2¼ inches = 1 nail.
4 nails = 1 quarter.
4 quarters = 1 yard.
3 quarters = 1 Flemish ell.
5 quarters = 1 English ell.
6 quarters = 1 French ell.

COMPARATIVE MEASURE OF LENGTH.

3 miles = 1 league, *marked* lea.
2¾ " = 1 French league.
3⅜ " = 1 Spanish league.
4 " = 1 German mile.
3¼ " = 1 Dutch mile.
$\frac{11}{12}$ mile = 1 Italian mile.
$\frac{13}{14}$ " = 1 Russian verst.
$1\frac{3}{22}$ " = 1 Scotch mile.
$1\frac{3}{11}$ " = 1 Irish mile.

MEASURE OF SURFACE, OR SQUARE MEASURE.

144 square inches = 1 square foot.
9 " feet = 1 " yard.
272¼ " feet = 1 " rod or pole.
30¼ " yards = 1 " pole.
40 " rods = 1 " rood.
4 " roods = 1 " acre.
640 " acres = 1 " mile.

SPECIAL MEASURE OF SURFACE.

For Land.

62·7264 square inches = 1 square link.
10,000 " links = 1 " chain.
10 " chains = 1 acre.

Note.—By these tables, land measure and artificers' work are computed.

MEASURE OF SOLIDITY, OR CUBIC MEASURE.

1728 cubic inches - - - - - - = 1 cubic foot.
27 " feet - - - - - - = 1 cubic yard.
50 " " of round timber = 1 ton.
40 " " of hewn " = 1 ton.
40 " " of shipping " = 1 ton.
16 " " - - - - - - - - = 1 cord foot.
8 cord feet or 128 cubic feet = 1 cord of wood.

Note.—A cubic foot is equal to 2200 *cylindrical* inches, or 3300 spherical inches, or 6600 conical inches. A cubic foot of water equals 62½ lbs.; a cylindrical foot equals 49·1; a cubic inch equals ·03617 lbs.; a cylindrical inch equals ·02642 lbs.

WEIGHTS AND MEASURES.

Dry Measure.

2 pints = 1 quart.
4 quarts = 1 gallon.
8 quarts = 1 peck.
4 pecks = 1 bushel.

U. S. AND IMPERIAL (BRITISH) MEASURES.

1 quarter of wheat = 8 bushels.
231 cubic inches = 1 Winchester or U. S. gallon.
282 " " = 1 " ale gallon.
2150·42 " " = 1 " or U. S. bushel.
277·274 " " = 1 Imperial gallon, for dry, beer, and wine.
2218·192 " " = 1 " bushel.

Note.—The Winchester bushel (so called because the standard measures were kept at Winchester) is 18½ inches diameter, and 8 inches deep, and contains 2150·42 cubic inches.

MISCELLANEOUS MEASURE.

For Various Purposes.

1 chaldron = 36 bushels, or 57·25 cubic feet.
1 perch of stone = $16\frac{1}{2}$ cubic feet.
1 hand = 4 inches.
1 span = 9 inches.
1 cubic foot of anthracite coal, weighs from 50 to 55 lbs.
1 " " bituminous coal, " " 42 " 55 "
1 " " Cumberland coal, " 53 "
1 " " charcoal, (hard wood) " 18·5 "
1 " " " (pine) " 18 "

MEASURES OF WEIGHT.—TROY.

By which Gold, Silver, and Precious Stones are weighed.

24 grains = 1 pennyweight.
20 pennyweights = 1 ounce.
12 ounces = 1 pound.

Note.—An ounce of gold is divided into 24 equal parts, called carats, and an ounce of silver into 20 parts, called pennyweights; therefore, to distinguish fineness of metals, such gold as will abide the fire, without loss, is accounted 24 carats fine; if it lose 2 carats in trial, it is called 22 carats fine, &c. A pound of silver which loses nothing in trial is 12 ounces fine; but if it lose 3 pennyweights, it is 11 ounces 17 pennyweights fine, &c.

AVOIRDUPOIS, OR THE GENERAL MEASURES OF WEIGHT.

$27\frac{11}{32}$ Troy grains = 1 dram.
16 drams = 1 ounce.
16 ounces = 1 pound.

28 pounds = 1 quarter.
4 quarters = 1 cwt.
20 cwt. = 1 ton.

1 lb. avoir. = 14 oz. 11 pwt. 16 gr. troy.
1 oz. " = 18 " $5\frac{1}{2}$ " "
1 dr. " = 1 " $3\frac{11}{32}$ " "
7000 troy grains = 1 lb. avoirdupois.
5760 " " = 1 lb. troy.
175 " pounds = 144 lbs. avoirdupois.
175 " ounces = 192 oz. "
$437\frac{1}{2}$ " grains = 1 oz. "
1 " pound = ·8228 lb. "

THE RELATIVE VALUE OF TROY AND AVOIRDUPOIS WEIGHTS.[*]

Troy lb. Avoir. lb.	1 0·823	2 1·646	3 2·469	4 3·291	5 4·114	6 4·937	7 5·760	8 6·583	9 7·406
Avoir lb. Troy lb.	1 1·215	2 2·431	3 3·646	4 4·861	5 6·076	6 7·292	7 8·507	8 9·722	9 10·937

[*] By comparing the number of grains in the advoirdupois and troy pound and ounce, respectively, it appears that the troy pound is less than the avoirdupois in the proportion of 14 to 17.0138; but the troy ounce is greater than the avoirdupois in the proportion of 79 to 72. Hence, the following approximating rules for changing avoirdupois weight to troy, and troy to advoirdupois, will often be found very convenient and useful.

ALE AND BEER MEASURE.

Pints.
2 = 1 quart.
8 = 4 = 1 gallon.
72 = 36 = 9 = 1 firkin.
144 = 72 = 18 = 2 = 1 kilderkin.
288 = 144 = 36 = 4 = 2 = 1 barrel.
432 = 216 = 54 = 6 = 3 = 1½ = 1 hogshead.
576 = 288 = 72 = 8 = 4 = 2 = 1⅓ = 1 puncheon.
864 = 432 = 108 = 12 = 6 = 3 = 2 = 1½ = 1 butt.

The standard U. S. gallon measures 231 cubic inches, and contains 8·3388822 pounds avoirdupois = 58372·1757 grains troy, of distilled water, at its maximum density 39·83° Fahrenheit, and 30 inches barometer height.

WINE MEASURE.

Pints.
2 = 1 quart.
8 = 4 = 1 gallon.
336 = 168 = 42 = 1 tierce.
504 = 252 = 63 = 1½ = 1 hogshead.
672 = 336 = 84 = 2 = 1⅓ = 1 puncheon.
1008 = 504 = 126 = 3 = 2 = 1½ = 1 pipe.
2016 = 1008 = 252 = 6 = 4 = 3 = 2 = 1 ton.

The English Imperial gallon measures 277·274 cubic inches, containing 10 lbs. avoirdupois of distilled water, weighed in air, at the temperature of 62°, the barometer at 30 inches.

SQUARE MEASURE.

Inches.	Feet.	Yards.	Rods.	Roods.	Acres.	Square mètres.
1	.00694	.000772	.0000255	.00000064	.000000159	.000645
144	1	.111	.00376	.0000918	.000023	.0929
1296	9	1	.0331	.000826	.0002062	.8361
39204	272½	30¼	1	.025	.00625	25.292
1568160	10890	1210	40	1	.25	1011.7
6272640	43560	4840	160	4	1	4046.7

CUBIC MEASURE.

Inches.	Feet.	Yards.	Cubic metre.
1	.0005788	.000002144	.000016386
1728	1	.03704	.028315
46656	27	1	.764513

USEFUL NUMBERS IN CALCULATING WEIGHTS AND MEASURES, ETC.

Square inches	×	·007	=	square feet
Circular inches	×	·00546	=	“ “
Square feet	×	·111	=	square yards
Cube feet	×	7·48	=	U. S. gallons
Cube inches	×	5·004329	=	“ “
Cylindrical inches	×	·0034	=	“ “
U. S. gallons	×	·13367	=	cube feet

CUBIC, OR SOLID MEASURE.

To find the Cubical Contents in a Stick of Timber.

If all the dimensions are in feet, multiply the length by the breadth, and this product by the depth, to obtain the number of cubic feet.

If the length is in feet and the width and depth in inches, multiply the length by the width, and this product by the depth in inches; then divide the last product by 144 for the cubic feet.

If all the dimensions are in feet and inches, reduce the whole to inches; then multiply the length, breadth and depth together, and divide the product by 1728, to obtain the cubic feet.

FOREIGN MEASURES OF LENGTH COMPARED WITH AMERICAN.

Places.	Measures.	Inches.	Places.	Measures.	Inches.
Amsterdam,	Foot	11·14	Malta	Foot	11·17
Antwerp	“	11·24	Moscow	“	13·17
Bavaria	“	11·42	Naples	Palmo	10·38
Berlin	“	12·19	Prussia	Foot	12·36
Bremen	“	11·38	Persia	Arish	38·27
Brussels	“	11·45	Rhineland	Foot	12·35
China	“ mathematic	13·12	Riga	“	10·79
“	“ builder’s	12·71	Rome	“	11·60
“	“ tradesman’s	13·32	Russia	“	13·75
“	“ surveyor’s	12·58	Sardinia	Palmo	9·78
Copenhagen	“	12 35	Sicily	“	9·53
Dresden	“	11·14	Spain	Foot	11·03
England	“	12·00	“	Toesas	66·72
Florence	Braccio	21·69	“	Palmo	8·64
France	Pied de Roi	12·79	Strasburg	Foot	11·39
“	Metre	39·381	Sweden	“	11·69
Geneva	Foot	19·20	Turin	“	12·72
Genoa	Palmo	9·72	Venice	“	13·40
Hamburg	Foot	11·29	Vienna	“	12·45
Hanover	“	11·45	Zurich	“	11·81
Leipsic	“	11·11	Utrecht	“	10·74
Lisbon	“	12·96	Warsaw	“	14 03
“	Palmo	8·64			

The French unit of length, called the metre, has been taken as being the ten millionth part of the quadrant of a meridian passing through Paris; that is to say, the ten-millionth part of the distance between the equator and the pole, measured through Paris. It is equal to 39·3707898 inches. The metre is divided into one thousand millimetres, one hundred centimetres, and ten decimeters; while a decameter is ten metres; a hectometre one hundred metres, a kilometre one thousand metres, and a myriametre ten thousand metres. The following table gives the value of these measurements in English inches and yards:

	In English Inches.	In English Yards.
Millimetre	0·03937	0·0010936
Centimetre	0·39371	0·0109363
Decimetre	3·93708	0·1093633
Metre	39·37079	1·0936331
Decametre	393·70790	10·9363310
Hectometre	3937·07900	109·3633100
Kilometre	39370·79000	1093·6331000
Myriametre	393707·90000	10936·3310000

One English yard is equal to 0·91438 metre; while one mile is equal to 1·60931 kilometres.

Unit of Surface.—For the unit of surface, the square inch, foot, and yard adopted in this country and in England are replaced in the metric system by the square millimetre, centimetre, decimetre, and metre.

1 square metre = 1·1960333 square yards.
1 square inch = 6·4513669 square centimetres.
1 square foot = 9·2899683 square decimetres.
1 square yard = 0·83609715 square metre.

CONVERSION OF ENGLISH INCHES INTO CENTIMETRES.

Inches.	0	1	2	3	4	5	6	7	8	9
	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.	Ct. Mt.
0	0·000	2·540	5·080	7·620	10·16	12·70	15·24	17·78	20.32	22.86
10	25·40	27·90	30·48	33·02	35·56	38·10	40·64	43·18	45·72	48·26
20	50·80	53·34	55·88	58·42	60·96	63·50	66·04	68·58	71·12	73·66
30	76·20	78·74	81·28	83·82	86·36	88·90	91·44	93·98	96·52	99·06
40	101·60	104·14	106·68	109·22	111·76	114·30	116·84	119·38	121·92	124·46
50	127.00	129·54	132·08	134·62	137·16	139·70	142·24	144·78	147·32	149·86
60	152·40	154·94	157·48	160·02	162·56	165·10	167·64	170·18	172·72	175·26
70	177.80	180·34	182·88	185·42	187·96	190·50	193·04	195·58	198·12	200·96
80	203·20	205 74	208·28	210·82	213·36	215·90	218·44	220·98	223·52	226·06
90	228·60	231·14	233·68	236·22	238·76	241·30	243·84	246·38	248·92	251·46
100	254.00	256.54	259·08	261·62	264·16	266·70	269·24	271·78	274·32	276·85

CONVERSION OF CENTIMETRES INTO ENGLISH INCHES.

Ct. Mt.	0	1	2	3	4	5	6	7	8	9
	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
0	0·000	0·394	0·787	1·181	1·575	1·969	2·362	2·756	3·150	3·543
10	3·937	4·331	4·742	5·118	5·512	5·906	6·299	6·693	7·087	7·480
20	7·874	8·268	8·662	9·055	9·449	9·843	10·236	10·630	11·024	11·418
30	11·811	12·205	12·599	12·992	13·386	13·780	14·173	14·567	14·961	15·355
40	15·748	16·142	16·536	16·929	17·323	17·717	18·111	18·504	18·898	19·292
50	19·685	20·079	20·473	20·867	21·260	21·654	22·048	22·441	22·835	23·229
60	23·622	24·016	24·410	24·804	25·197	25·591	25·985	26·378	26·772	27·166
70	27·560	27·953	28·347	28·741	29·134	29·528	29·922	30·316	30·709	31·103
80	31·497	31·890	32·284	32·678	33·071	33·465	33·859	34·253	34·646	35·040
90	35·434	35·827	36·221	36·615	37·009	37·402	37·796	38·190	38·583	38·977
100	39·370	39·764	40·158	40·552	40·945	41.339	41·733	42·126	42·520	42·914

CONVERSION OF ENGLISH FEET INTO METRES.

Feet.	0	1	2	3	4	5	6	7	8	9
	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.	Met.
0	0.000	0·3048	0·6096	0·9144	1·2192	1·5239	1·8887	2·1335	2·4383	2·7431
10	3·0479	3·3527	3·6575	3·9623	4·2671	4·5719	4·8767	5·1815	5·4863	5·7911
20	6·0359	6·4006	6·7055	7·0102	7·3150	7·6198	7·9246	8·2294	8·5342	8·8390
30	9·1438	9·4486	9·7534	10·058	10·363	10·668	10·972	11·277	11·582	11·887
40	12·192	12·496	12·801	13·106	13·411	13·716	14·020	14·325	14·630	14·935
50	15·239	15·544	15·849	16·154	16·459	16·763	17·068	17·373	17·678	17·983
60	18·287	18·592	18·897	19·202	19·507	19·811	20·116	20·421	20·726	21·031
70	21·335	21·640	21·945	22·250	22·555	22·859	23·164	23·469	23·774	24·079
80	24·383	24·688	24·993	25·298	25·602	25·907	26·212	26·517	26·822	27·126
90	27·431	27·736	27·041	28·346	28·651	28·955	29·260	29·565	29·870	30·174
100	30·479	30·784	31·089	31·394	31.698	32·003	32·308	32·613	32·918	33·222

CONVERSION OF METRES INTO ENGLISH FEET.

Metres.	0	1	2	3	4	5	6	7	8	9
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
0	0·000	3·2809	6·5618	9·8427	13·123	16·404	19·685	22·966	26·247	29·528
10	32·809	36·090	39·371	42·651	45·932	49·213	52·494	55·775	59·056	62·337
20	65·618	68·899	72·179	75·461	78·741	82·022	85·303	88·584	91·865	95·146
30	98·427	101·71	104·99	108·27	111·55	114·83	118·11	121·39	124·67	127·96
40	131·24	134·52	137·80	141·08	144·36	147·64	150·92	154·20	157·48	160·76
50	164·04	167.33	170·61	173·89	177·17	180·45	183·73	187·01	190·29	193·57
60	196·85	200·13	203·42	206·70	209·98	213·26	216·54	219·82	223·10	226·38
70	229·66	232·94	236·22	239·51	242·79	246·07	249·35	252·63	255·91	259·19
80	262·47	265·75	269·03	272·31	275·60	278·88	282·16	285·44	288·72	292·00
90	295·28	298·56	391·84	305·12	308·40	311·69	314·97	318·25	321·53	324·81
100	328·09	331·37	334·65	337·93	341·21	344.49	347·78	351·06	354·34	357·62

FRENCH SQUARE MEASURE, UNITED STATES.

1 square millimetre	=	.001549	square inches.
1 square centimetre	=	.154988	"
1 square decimetre	=	15.4988	"
1 square metre	=	10.763058	square feet.
1 square decametre	=	1076.3058	"
1 square decare	=	10763.058	"
1 square hectare	=	2.47086	U. S. acres.
1 square kilometre	=	247.086	"
1 square myriametre	=	24708.6	"

FRENCH CUBIC OR SOLID MEASURE, U. S.

				Cubic Inches.
Millitre, or cubic centimetre			=	.0610165
10 millitres	make	1 centilitre	=	.610165
10 centilitres	"	1 decilitre	=	6.10165
10 decilitres	"	1 litre	=	61.0165
10 litres	"	1 decilitre	=	610.165
				Cubic feet.
10 decalitres	"	1 hectolitre	=	3.53105
10 hectolitres	"	1 kilolitre or cubic metre	=	35.3105
10 kilolitres	"	1 myriolitre	=	353.105

FRENCH MEASURE, UNITED STATES STANDARD.

					Inches.
		1 millimetre	=	$\frac{1}{25}$ inch nearly, or	.0393685
10 millimetres	make	1 centimetre	=	$\frac{3}{8}$ inch full, or	.393685
10 centimetres	"	1 decimetre	=	4 inches nearly, or	3.93685
10 decimetres	"	1 METRE	=	3 feet $3\frac{3}{8}$ inches +, or	39.3685
10 metres	"	1 decametre	=	32.871 feet, or	393.685
					Miles.
10 decametres	"	1 hectometre	=	328.071 feet, or	.0621347
10 hectometres	"	1 kilometre	=	3280.71 feet, $\frac{3}{8}$ or	.6213466
10 kilometres	"	1 myriametre	=	32807.1 feet, $6\frac{1}{5}$ or	6.213466

AVOIRDUPOIS WEIGHT.

Drams.	Ozs.	Lbs.	Qrs.	Cwts.	Tons.	French Grammes.
1	.0625	.0039	.000139	.000035	.00000174	1.771846
16	1	.0625	.00223	.000558	.000028	28.34954
256	16	1	.0357	.00893	.000447	453.59
7168	448	28	1	.25	.0125	12,700
28672	1792	112	4	1	.05	50,802
573440	35840	2240	80	20	1	1,016,048

Note.—The standard pound avoirdupois is the weight of 27·7015 cubic inches of distilled water at 39·83° Fahrenheit, barometer 30 inches, and weighed in the air.

TROY WEIGHT.

Grains.	Pwts.	Ozs.	Lbs.	French Grammes.
1	.04167	.00208	.0001736	.0648
24	1	.05	.004167	1.555
480	20	1	.0833	31.1035
5760	240	12	1	373.242

175 lbs. troy = 144 lbs. avoirdupois.
Lbs. avoirdupois × .82286 = lbs. troy.
Lbs. troy × 1.2153 = lbs. avoirdupois.

LONG MEASURE.

Inches.	Feet.	Yards.	Faths.	Poles.	Furlongs.	Miles.	French metres.
1	.083	.02778	.0139	.005	.000126	.0000158	.0254
12	1	.333	.1667	.0606	.00151	.0001894	.3048
36	3	1	.5	.182	.00454	.000568	.9144
72	6	2	1	.364	.0091	.001136	1.8287
198	16½	5½	2¾	1	.025	.003125	5.0291
7920	660	220	110	40	1	.125	201.16
63360	5280	1760	880	320	8	1	1609.315

A point = $\frac{1}{72}$ inch. A line = 6 points = $\frac{1}{12}$ inch. A palm = 3 inches. A span = 9 inches. A hand = 4 inches. A fathom = 6 feet. A cable's length = 120 fathoms = 720 feet. A Gunter's chain = 66 feet = 4 rods. 80 Gunter's chains = 1 mile. A nautical or sea-mile = 6086.07 feet, or $\frac{1}{21600}$ part of the earth's circumference at the equator = 1.152664 geographical or land miles. 1 degree at equator = 69.160 land miles. 1 land mile = .86755 of a nautical mile.

TABLE

SHOWING THE WEIGHT OF WATER.

1 cubic inch = .03617 pounds.
12 cubic inches = .434 "
1 cubic foot = 62.5 "
1 cubic foot = 7.50 U. S. gallons.
1.8 cubic foot = 112.00 pounds.
35.84 cubic feet = 2240.00 "
1 cylindrical inch = .02842 "
12 cylindrical inches = .341 "
1 cylindrical foot = 49.10 "
1 cylindrical foot = 6.00 U. S. gallons.
2.282 cylindrical feet = 112.00 pounds.
45.64 cylindrical feet = 2240.00 "
11.2 Imperial gallons = 112.00 "
224 Imperial gallons = 2240.00 "
13.44 U. S. gallons = 112.00 "
268.8 U. S. gallons = 2240.00 "

TABLE

SHOWING THE WEIGHT OF WATER AT DIFFERENT TEMPERATURES

Temperature, Fahrenheit.	Weight of a cubic foot in pounds.	Temperature, Fahrenheit.	Weight of a cubic foot in pounds.
40°	62.408	172°	60.72
42°	62.406	182°	60.5
52°	62.377	192°	60.28
62°	62.321	202°	60.05
72°	62.25	212°	59.82
82°	62.15	230°	59.37
92°	62.04	250°	58.85
102°	61.92	275°	58.17
112°	61.78	300°	57.42
122°	61.63	350°	55.94
132°	61.47	400°	54.34
142°	61.30	450°	52.70
152°	61.11	500°	51.02
162°	60.92	600°	47.64

DIAMETRAL PITCH.

This method of denoting the size of gear wheels is based upon the following theory:

The diameter of the wheel at the pitch circle is supposed to be divided into as many parts as there are teeth in the wheel; then the length of one of these parts is the diametral pitch.

Suppose we are given a diametral pitch of 2. To obtain the corresponding arc pitch we divide 3·1416 (the relation of the circumference to the diameter) by 2 (the diametral pitch) and 3·1416 ÷ 2 = 1·57 = the arc pitch in inches and decimal parts of an inch. If we are given an arc pitch to find a corresponding diametral pitch, we again simply divide 3·1416 by the given arc pitch. Example: What is the diametral pitch of a wheel whose arc pitch is 1½ inches? Here 3·1416 ÷ 1·5 = 2·09 = diametral pitch.

Below is Brown & Sharpe's table of circular and diametral pitches, which will be found very useful.

Diametral pitch.	Arc pitch.	Arc pitch.	Diametral.
2	1·57	1·75 inch.	1·79
2·25	1·39	1·5 "	2·09
2·5	1·25	1·4375 "	2·18
2·75	1·14	1·375 "	2·28
3	1·04	1·3125 "	2·39
3·5	·890	1·25 "	2·51
4	·785	1·1875 "	2·65
5	·628	1·125 "	2·79
6	·523	1·0625 "	2·96
7	·448	1·0000 "	3·14
8	·392	0·9375 "	3·35
9	·350	0·875 "	3·59
10	·314	0·8125 "	3·86
11	·280	0·75 "	4·19
12	·261	0·6875 "	4·57
14	·224	0·625 "	5·03
16	·196	0·5625 "	5·58
18	·174	0·5 "	6·28
20	·157	0·4375 "	7·18
22	·143	0·375 "	8·38
24	·130	0·3125 "	10·06
26	·120	0·25 "	12·56

In using diametral pitch to order wheels it is sufficient to employ two places of decimals; but where mathematical calculations are concerned it is better to use three places of decimals.

PAPER.

1 ream = 20 quires = 480 sheets.
1 quire = 24 sheets.

DRAWING PAPER.

Cap	13 × 16 inches.	Columbier	34 × 23 inches.
Demy	20 " 15 "	Atlas	33 " 26 "
Medium	22 " 17 "	Theorem	34 " 28 "
Royal	24 " 19 "	Double Elephant	40 " 26 "
Super Royal	27 " 19 "	Antiquarian	52 " 31 "
Imperial	30 " 21 "	Emperor	40 " 60 "
Elephant	28 " 22 "	Uncle Sam	48 "120 "

CONTINUOUS COLOSSAL DRAWING PAPER, No. A and No. B, 56 inches wide, and of any required length.

TRACING PAPER.

Double Crown	30 × 20 inches.	Glazed or Crystal. Yellow or Blue Wove.
Double Double Crown	40 " 30 "	
Double Double Double Crown.	60 " 40 "	

SHEET ZINC AND IRON.

SHEET ZINC. Size 84 in. by 24, 28, 32, 36 and 40 inches.

RUSSIA SHEET IRON. Size 28 × 56 in. = 10.88 sq. feet.

Zinc gage.	WIDTH OF SHEET.			Bir. W. gage.	Russian gage.	WEIGHT PER		Bir. W. gage.
	24	32	40			Sheet.	Sq. ft.	
No.	Pounds.	Pounds.	Pounds.	No.	No.	Pounds.	Pounds.	No.
8	6.23	9.68	12.1	28	7	6.25	0.574	29
9	7.20	11.2	14.	27	8	7.25	0.666	28
10	8.	12.4	15.6	26	9	8.	0.735	27
11	8.90	13.8	17.3	25	10	9.	0.827	26
12	10.1	15.7	19.7	24½	11	10.	0.918	25
13	11.1	17.3	21.6	23	12	10.75	0.987	24½
14	12.4	19.3	24.1	22	13	11.75	1.08	24
15	16.2	25.2	31.6	21	14	12.5	1.15	23¼
16	17 4	27.1	33 9	20	15	13.5	1.24	22⅝
18	21.9	34.	42.6	18	16	14.5	1.33	21½

LENGTH IN INCHES OF PENNY NAILS.

1 in.	1.25	1.5	1.75	2	2.25	2.5	2.75	3	3.25	3.5	4	4.25	5	5.5	6
2*d.*	3*d.*	4*d.*	5*d.*	6*d.*	7*d.*	8*d.*	9*d.*	10	12	16	20	30	40	50	60

TABLE AND RULE,

FOR THE COMPUTATION OF THE SIZES OF TAPPING HOLES FOR PIPE TAPS.

Inside diameter.	Outside diameter.	Outside, allowing for the taper.	Diameter at bottom of thread — size of drill in inches.
⅛	·405	·362	·298
¼	·54	·497	·401
⅜	·675	·632	·509
½	·84	·777	·654
¾	1·05	·987	·837
1	1·315	1·252	1·102
1¼	1·66	1·586	1·436
1½	1·9	1·826	1·676
2	2·375	2·301	2·085
2½	2·875	2·769	2·553
3	3·5	3·399	3·183
3½	4·	3·899	3·683
4	4·5	4·399	4·183

The outside diameters are from Morris and Tasker's table of standard sizes.

The taper used in calculating is that given by Pratt and Whitney, 1 inch to foot, and the length of threads on ⅛ to ⅜ is ½ inch, ½ to 1 is ¾, 1¼ to 2 is ⅞, and 2½ to 4 inches is 1¼ inch. The rule for computing size of drills is: Subtract from the outside diameter (after allowing for the taper) the product of the pitch by 1·732, which gives the diameter at the bottom of the thread, or the size of the required drill.

TAPS FOR MACHINE SCREWS.

Diameter.	Wire gage size.	No. threads to inch.
7/64	No. 4	36 & 40
9/64	" 6	30, 32, 36 & 40
⅛	—	30, 32, 36 & 48
5/32	" 8	30 & 32
3/16	" 10	20, 22 & 24
7/32	" 12	20, 22 & 24
¼	" 14	16, 18, 20, 22 & 24
17/64	" 16	16, 18, 20 & 22
9/32	" 18	16, 18 & 20
5/16	" 20	16, 18 & 20
⅜	" 24	14, 16 & 18

ORDINARY SIZES AND THICKNESSES OF IRON WASHERS.

Diameter of washer.	Size of hole in washer.	Thickness, wire gage.	Size of bolt.	Diameter of washer.	Size of hole in washer.	Thickness, wire gage.	Size of bolt.
	¼	No. 18	3/16	1¾	11/16	No. 10	⅝
⅝	5/16	" 16	¼	1¾	¾	" 10	11/16
¾	5/16	" 16	¼	1¾	13/16	" 10	¾
⅞	⅜	" 16	5/16	2	13/16	" 10	¾
1	7/16	" 16	⅜	2¼	15/16	" 9	⅞
1⅛	½	" 14	7/16	2½	1 1/16	" 9	1
1¼	½	" 14	7/16	2¾	1¼	" 9	1⅛
1¼	9/16	" 14	½	3	1⅜	" 9	1¼
1⅜	9/16	" 12	½	3½	1½	" 9	1⅜
1⅜	⅝	" 12	9/16	3½	1⅝	" 8	1½
1½	⅝	" 12	9/16	4	1⅞	" 8	1¾
1½	11/16	" 12	⅝	4	2⅛	" 8	2

IRON WIRE ROPE.

HOISTING ROPE, 19 WIRES TO THE STRAND.

Trade number.	Circumference in inches.	Diameter.	Trade number.	Circumference in inches.	Diameter.
1	6¾	2¼	8	3⅛	1
2	6	2	9	2¾	⅞
3	5½	1¾	10	2¼	¾
4	5	1⅝	10¼	2	⅝
5	4⅜	1½	10½	1⅝	9/16
6	4	1¼	10¾	1½	½
7	3½	1⅛	..	..	..

ROPE, WITH 7 WIRES TO THE STRAND.

Trade number.	Circumference in inches.	Diameter.	Trade number.	Circumference in inches.	Diameter.
11	4⅝	1½	20	1⅝	½
12	4¼	1⅜	21	1⅜	7/16
13	3¾	1¼	22	1¼	⅜
14	3⅜	1⅛	23	1⅛	5/16
15	3	1	24	1	9/32
16	2⅝	⅞	25	⅞	¼
17	2⅜	¾	26	¾	7/32
18	2⅛	11/16	27	⅝	3/16
19	1⅞	⅝	..	..	..

TABLE,

Containing the Diameters, Circumferences, and Areas of Circles, and the Sides of an Equal Square from $\frac{1}{16}$ Inch up to 26 Feet.

Diam.	Circum.	Area.	Side of equal square.
Inch.			
$\frac{1}{16}$	·1963	·0030	....
$\frac{1}{8}$	·3927	·0122	·1107
$\frac{3}{16}$	·5890	·0276	....
$\frac{1}{4}$	·7854	·0490	·2155
$\frac{5}{16}$	·9817	·0767	....
$\frac{3}{8}$	1·1781	·1104	·3223
$\frac{7}{16}$	1·3744	·1503	....
$\frac{1}{2}$	1·5708	·1963	·4311
$\frac{9}{16}$	1·7671	·2485	....
$\frac{5}{8}$	1·9635	·3068	·5438
$\frac{11}{16}$	2·1598	·3712	....
$\frac{3}{4}$	2·3562	·4417	·6646
$\frac{13}{16}$	2·5525	·5185	....
$\frac{7}{8}$	2·7489	·6013	·7756
$\frac{15}{16}$	2·9452	·6903	....
1 in.	3·1416	·7854	·8862
$\frac{1}{16}$	3·3379	·8861	....
$\frac{1}{8}$	3·5343	·9940	·9969
$\frac{3}{16}$	3·7306	1·1075	....
$\frac{1}{4}$	3·9270	1·2271	1·0775
$\frac{5}{16}$	4·1233	1·3529	....
$\frac{3}{8}$	4·3197	1·4848	1·2185
$\frac{7}{16}$	4·5160	1·6229	....
$\frac{1}{2}$	4·7124	1·7671	1·3293
$\frac{9}{16}$	4·9087	1·9175	....
$\frac{5}{8}$	5·1051	2·0739	1·4401
$\frac{11}{16}$	5·3014	2·2365	....
$\frac{3}{4}$	5·4978	2·4052	1·5508
$\frac{13}{16}$	5·6941	2·5801	....
$\frac{7}{8}$	5·8905	2·7611	1·6616
$\frac{15}{16}$	6·0868	2·9483	....
2 in.	6·2832	3·1416	1·7724
$\frac{1}{16}$	6·4795	3·3411	....
$2\frac{1}{8}$ in.	6·6759	3·5465	1·8831
$\frac{3}{16}$	6·8722	3·7582	....
$\frac{1}{4}$	7·0686	3·9760	1·9939
$\frac{5}{16}$	7·2640	4·2001	....
$\frac{3}{8}$	7·4613	4·4302	2·1047
$\frac{7}{16}$	7·6576	4·6664	....
$\frac{1}{2}$	7·8540	4·9087	2·2155
$\frac{9}{16}$	8·0503	5·1573	....
$\frac{5}{8}$	8·2467	5·4119	2·3262
$\frac{11}{16}$	8·4430	5·6727	....
$\frac{3}{4}$	8·6394	5·9395	2·4370
$\frac{13}{16}$	8·8357	6·2126	....
$\frac{7}{8}$	9·0321	6·4918	2·5478
$\frac{15}{16}$	9·2284	6·7772	....
3 in.	9·4248	7·0686	2·6586
$\frac{1}{16}$	9·6211	7·3662	....
$\frac{1}{8}$	9·8175	7·6699	2·7694
$\frac{3}{16}$	10·0138	7·9798	....
$\frac{1}{4}$	10·2120	8·2957	2·8801
$\frac{5}{16}$	10·4065	8·6179	....
$\frac{3}{8}$	10·6029	8·9462	2·9909
$\frac{7}{16}$	10·7992	9·2806	....
$\frac{1}{2}$	10·9956	9·6211	3·1017
$\frac{9}{16}$	11·1919	9·9678	....
$\frac{5}{8}$	11·3883	10·3206	3·2124
$\frac{11}{16}$	11·5846	10·6796	....
$\frac{3}{4}$	11·7810	11·0446	3·3232
$\frac{13}{16}$	11·9773	11·4159	....
$\frac{7}{8}$	12·1737	11·7932	3·4340
$\frac{15}{16}$	12·3700	12·1768	....
4 in.	12·5664	12·5664	3·5448
$\frac{1}{16}$	12·7627	12·9622	....
$\frac{1}{8}$	12·9591	13·3640	3·6555
$\frac{3}{16}$	13·1554	13·7721	....

Diam.	Circum.	Area.	Side of equal square.
4¼ in.	13·3518	14·1862	3·7663
5/16	13·5481	14·6066	....
3/8	13·7445	15·0331	3·8771
7/16	13·9408	15·4657	....
½	14·1372	15·9043	3·9880
9/16	14·3335	16·3492	....
5/8	14·5299	16·8001	4.0987
11/16	14·7262	17·2573	....
¾	14·9226	17·7205	4·2095
13/16	15·1189	18·1900	....
7/8	15·3153	18·6555	4·3202
15/16	15.5716	19·1472	....
5 in.	15·7080	19·6350	4·4310
1/16	15·9043	20·1290	....
1/8	16·1007	20·6290	4·5417
3/16	16·2970	21·1252	....
¼	16·4934	21·6475	4·6525
5/16	16·6897	22·1661	....
3/8	16·8861	22·6907	4·7633
7/16	17·0824	23·2215	....
½	17·2788	23·7583	4·8741
9/16	17·4751	24·3014	....
5/8	17·6715	24·8505	4·9848
11/16	17·8678	25·4058	....
¾	18·0642	25·9672	5·0956
13/16	18·2605	26·5348	....
7/8	18·4569	27·1085	5·2064
15/16	18·6532	27·6884	....
6 in.	18·8496	28·2744	5·3172
1/16	19·0459	28·8665	....
1/8	19·2423	29·4647	5·4280
3/16	19·4386	30·0798	....
¼	19·6350	30·6796	5·5388
5/16	19·8313	31·2964	....
3/8	20·0277	31·9192	5·6495
7/16	20·2240	32·5481	....
½	20·4204	33·1831	5·7603
9/16	20·6167	33·8244	....
5/8	20·8131	34·1747	5·8711
11/16	21·0094	35·1252	....
¾	21·2508	35·7847	5·9819
13/16	21·4021	36·4505	....
7/8	21·5985	37·1226	6·0927
15/16	21·7948	37·8005	....
7 in.	21·9912	38·4846	6·2034
1/16	22·1875	39·1749	....
7⅛ in.	22·3839	39·1783	6·3142
3/16	22·5802	40·5469	....
¼	22·7766	41·2825	6·4350
5/16	22·9729	41·9974	....
3/8	23·1693	42·7184	6·5358
7/16	23·3656	43·4455	....
½	23·5620	44·1787	6·6465
9/16	23·7583	44·9181	....
5/8	23·9547	45·6636	6·7573
11/16	24·1510	46·4153	....
¾	24·3476	47·1730	6·8681
13/16	24·5437	47·9370	....
7/8	24·7401	48·7070	6·9787
15/16	24·9364	49·4833	....
8 in.	25·1328	50·2656	7·0897
1/16	25·3291	51·0541	....
1/8	25·5255	51·8468	7·2005
3/16	25·7281	52·8994	....
¼	25·9182	53·4562	7·3112
5/16	26·1145	54·2748	....
3/8	26·3109	55·0885	7·4220
7/16	26·5072	55·9138	....
½	26·7036	56·7541	7·5328
9/16	26·8999	57·5887	....
5/8	27·0963	58·4264	7·6436
11/16	27·2926	59·7762	....
¾	27·4890	60·1321	7·7544
13/16	27·6853	60·9943	....
7/8	27·8817	61·8625	7·8651
15/16	28·0780	62·7369	....
9 in.	28·2744	63·6174	7·9760
1/16	28·4707	64·5041	....
1/8	28·6671	65·3968	8·0866
3/16	28·8634	66·2957	....
¼	29·0598	67·2007	8·1974
5/16	29·2561	68·1120	....
3/8	29·4525	69·0293	8·3081
7/16	29·6488	69·9528	....
½	29·8452	70·8823	8·4190
9/16	30·0415	71·8181	....
5/8	30·2379	72·7599	8·5297
11/16	30·4342	73·7079	....
¾	30·6306	74·6620	8·6405
13/16	30·8269	75·6223	....
7/8	31·0233	76·5887	8·7513
15/16	31·2195	77·5613	....

Diam.	Circum.	Area.	Side of equal Square.
10 in.	31·416	78·540	8·8620
⅛	31·808	80·515	8·9728
¼	32·201	82·516	9·0836
⅜	32·594	84·540	9·1943
½	32·986	86·590	9·3051
⅝	33·379	88·664	9·4159
¾	33·772	90·762	9·5267
⅞	34·164	92·885	9·6375
11 in.	34·557	95·033	9·7482
⅛	34·950	97·205	9·8590
¼	35·343	99·402	9·9698
⅜	35·735	101·623	10·080
½	36·128	103·869	10·191
⅝	36·521	106·139	10·302
¾	36·913	108·434	10·413
⅞	37·306	110·753	10·523
12 in.	37·699	113·097	10·634
⅛	38·091	115·466	10·745
¼	38·484	117·859	10·856
⅜	38·877	120·276	10·966
½	39·270	122·718	11·077
⅝	39·662	125·184	11·188
¾	40·055	127·676	11·299
⅞	40·448	130·192	11·409
13 in.	40·840	132·732	11·520
⅛	41·233	135·297	11·631
¼	41·626	137·886	11·742
⅜	42·018	140·500	11·853
½	42·411	143·139	11·963
⅝	42·804	145·802	12·074
¾	43·197	148·489	12·185
⅞	43·589	151·201	12·296
14 in.	43·982	153·938	12·406
⅛	44·375	156·699	12·517
¼	44·767	159·485	12·628
⅜	45·160	162·295	12·739
½	45·553	165·130	12·850
⅝	45·945	167·989	12·960
¾	46·338	170·873	13·071
⅞	46·731	173·782	13·182
15 in.	47·124	176·715	13·293
⅛	47·516	179·672	13·403
¼	47·909	182·654	13·514
⅜	48·302	185·661	13·625
15½ in.	48·694	188·692	13·736
⅝	49 087	191·748	13·847
¾	49·480	194·828	13·957
⅞	49·872	197·933	14·068
16 in.	50·265	201·062	14.179
⅛	50·658	204·216	14·290
¼	51·051	207·394	14·400
⅜	51·443	210·597	14·511
½	51·836	213·825	14·622
⅝	52·229	217·077	14·732
¾	52·621	220·353	14·843
⅞	53 014	223·654	14·954
17 in.	53·407	226·980	15·065
⅛	53·799	230·330	15·176
¼	54·192	233·705	15·286
⅜	54·585	237·104	15·397
½	54·978	240·528	15·508
⅝	55·370	243·977	15·619
¾	55·763	247·450	15·730
⅞	56·156	250·947	15·840
18 in.	56·548	254·469	15·951
⅛	56·941	258·016	16·062
¼	57·334	261·587	16·173
⅜	57·726	265·182	16·283
½	58·119	268·803	16·394
⅝	58·512	272·447	16·505
¾	58·905	276·117	16·616
⅞	59·297	279·811	16·727
19 in.	59·690	283·529	16·837
⅛	60·083	287·272	16·948
¼	60·475	291·039	17·060
⅜	60·868	294·831	17·170
½	61·261	298·648	17·280
⅝	61·653	302·489	17·391
¾	62·046	306·355	17·502
⅞	62·439	310·245	17·613
20 in.	62·832	314·160	17·724
⅛	63·224	318·099	17·834
¼	63·617	322·063	17·945
⅜	64·010	326·051	18·056
½	64·402	330·064	18·167
⅝	64·795	334·101	18·277
¾	65·188	338·163	18·388
⅞	65·580	342·250	18·499

Diam.	Circum.	Area.	Side of equal Square.	Diam.	Circum.	Area.	Side of equal Square.
21 in.	65·793	346·361	18·610	26½in.	83·252	551·547	23·484
⅛	66·366	350·497	18·721	⅝	83·645	556·762	23·595
¼	66·759	354·657	18·831	¾	84·037	562·002	23·708
⅜	67·151	358·841	18·942	⅞	84·430	567·267	23·816
½	67·544	363·051	19·053	27 in.	84·823	572·556	23·927
⅝	67·937	367·284	19·164	⅛	85·215	577·870	24·038
¾	68·329	371·543	19·274	¼	85·608	583·208	24·149
⅞	68·722	375·826	19·385	⅜	86·001	588·571	24·259
22 in.	69·115	380·133	19·496	½	86·394	593·958	24·370
⅛	69·507	384·465	19·607	⅝	86·786	599·370	24·481
¼	69·900	388·822	19·718	¾	87·179	604·807	24·592
⅜	70·293	393·203	19·828	⅞	87·572	610·268	24·703
½	70·686	397·608	19·939	28 in.	87·964	615·753	24·813
⅝	71·078	402·038	20·050	⅛	88·357	621·263	24·924
¾	71·471	406·493	20·161	¼	88·750	626·798	25·035
⅞	71·864	410·972	20·271	⅜	89·142	632·357	25·146
23 in.	72·256	415·476	20·382	½	89·535	637·941	25·256
⅛	72·649	420·004	20·493	⅝	89·928	643·594	25·367
¼	73·042	424·557	20·604	¾	90·321	649·182	25·478
⅜	73·434	429·135	20·715	⅞	90·713	654·839	25·589
½	73·827	433·731	20·825	29 in.	91·106	660·521	25·699
⅝	74·220	438·363	20·936	⅛	91·499	666·227	25·810
¾	74·613	443·014	21·047	¼	91·891	671·958	25·921
⅞	75·005	447·699	21·158	⅜	92·284	677·714	26·032
24 in.	75·398	452·390	21·268	½	92·677	683·494	26·143
⅛	75·791	457·115	21·379	⅝	93·069	689·298	26·253
¼	76·183	461·864	21·490	¾	93·462	695·128	26·364
⅜	76·576	466·638	21·601	⅞	93·855	700·981	26·478
½	76·969	471·436	21·712	30 in.	94·248	706·860	26·586
⅝	77·361	476·259	21·822	⅛	94·640	712·762	26·696
¾	77·754	481·106	21·933	¼	95·033	718·690	26·807
⅞	78·147	485·978	22·044	⅜	95·426	724·641	26·918
25 in.	78·540	490·875	22·155	½	95·818	730·618	27·029
⅛	78·932	495·796	22·265	⅝	96·211	736·619	27·139
¼	79·325	500·741	22·376	¾	96·604	742·644	27·250
⅜	79·718	505·711	22·487	⅞	96·996	748·694	27·361
½	80·110	510·706	22·598	31 in.	97·389	754·769	27·472
⅝	80·503	515·725	22·709	⅛	97·782	760·868	27·583
¾	80·896	520·769	22·819	¼	98·175	766·992	27·693
⅞	81·288	525·837	22·930	⅜	98·567	773·140	27·804
26 in.	81·681	530·930	23·041	½	98·968	779·313	27·915
⅛	82·074	536·047	23.152	⅝	99·353	785·510	28·026
¼	82·467	541·189	23·062	¾	99·745	791·732	28·136
⅜	82·859	546·356	23·373	⅞	100·138	797·978	28·247

Diam.	Circum.	Area.	Side of equal Square.	Diam.	Circum.	Area.	Side of equal Square.
32 in.	100·531	804·249	28·358	37½ in.	117·810	1104·46	33·232
⅛	100·924	810·545	28·469	⅝	118·202	1111·84	33·343
¼	101·316	816·865	28·580	¾	118·595	1119·24	33·454
⅜	101·709	823·209	28·691	⅞	118·988	1126·66	33·564
½	102·102	829·578	28·801	38 in.	119·380	1134·11	33·675
⅝	102·494	835·972	28·912	⅛	119·773	1141·59	33·786
¾	102·887	842·390	29·023	¼	120·166	1149·08	33·897
⅞	103·280	848·833	29·133	⅜	120·558	1156·61	34·008
33 in.	103·672	855·30	29·244	½	120·951	1164·15	34·118
⅛	104·055	861·79	29·355	⅝	121·344	1171·73	34·229
¼	104·458	868·30	29·466	¾	121·737	1179·32	34·340
⅜	104·850	874·84	29·577	⅞	122·129	1186·94	34·451
½	105·243	881·41	29·687	39 in.	122·522	1194·59	34·561
⅝	105·636	888·00	29·798	⅛	122·915	1202·26	34·672
¾	106·029	894·61	29·909	¼	123·307	1209·95	34·783
⅞	106·421	901·25	30·020	⅜	123·700	1217·67	34·894
34 in.	106·814	907·92	30·131	½	124·093	1225·42	35·005
⅛	107·207	914·61	30·241	⅝	124·485	1233·18	35·115
¼	107·599	921·32	30·352	¾	124·878	1240·98	35·226
⅜	107·992	928·06	30·463	⅞	125·271	1248·79	35·337
½	108·385	934·82	30·574	40 in.	125·664	1256·64	35·448
⅝	108·777	941·60	30·684	⅛	126·056	1264·50	35·558
¾	109·170	948·41	30·795	¼	126·449	1272·39	35·669
⅞	109·563	955·25	30·906	⅜	126·842	1280·31	35·780
35 in.	109·956	962·11	31·017	½	127·234	1288·25	35·891
⅛	110·348	968·99	31·128	⅝	127·627	1296·21	36·002
¼	110·741	975·90	31·238	¾	128·020	1304·20	36·112
⅜	111·134	982·84	31·349	⅞	128·412	1312·21	36·223
½	111·526	989·80	31·460	41 in.	128·805	1320·25	36·334
⅝	111·919	996·78	31·571	⅛	129·198	1328·32	36·445
¾	112·312	1003·7	31·681	¼	129·591	1336·40	36·555
⅞	112·704	1010·8	31·792	⅜	129·983	1344·51	36·666
36 in.	113·097	1017·87	31·903	½	130·376	1352·65	36·777
⅛	113·490	1024·95	32·014	⅝	130·769	1360·81	36·888
¼	113·883	1032·06	32·124	¾	131·161	1369·00	36·999
⅜	114·275	1039·19	32·235	⅞	131·554	1377·21	37·109
½	114·668	1046·30	32·346	42 in.	131·947	1385·44	37·220
⅝	115·061	1053·52	32·457	⅛	132·339	1393·70	37·331
¾	115·453	1060·73	32·567	¼	132·732	1401·98	37·442
⅞	115·846	1067·95	32·678	⅜	133·125	1410·29	37·552
37 in.	116·239	1075·21	32·789	½	133·518	1418·62	37·663
⅛	116·631	1082·48	32·900	⅝	133·910	1426·98	37·774
¼	117·024	1089·79	33·011	¾	134·303	1435·36	37·885
⅜	117·417	1097·11	33·021	⅞	134·696	1443·77	37·996

Diam.	Circum.	Area.	Side of equal Square.
43 in.	135·088	1452·20	38·106
⅛	135·481	1460·65	38·217
¼	135·874	1469·13	38·328
⅜	136·266	1477·63	38·439
½	136·659	1486·17	38·549
⅝	137·052	1494·72	38·660
¾	137·445	1503·30	38·771
⅞	137·837	1511·90	38·882
44 in.	138·230	1520·53	38·993
⅛	138·623	1529·18	39·103
¼	139·015	1537·86	39·214
⅜	139·408	1546·55	39·325
½	139·801	1555·28	39·436
⅝	140·193	1564·03	39·546
¾	140·586	1572·81	39·657
⅞	140·979	1581·61	39·768
45 in.	141·372	1590·43	39·879
⅛	141·764	1599·28	39·989
¼	142·157	1608·15	40·110
⅜	142·550	1617·04	40·211
½	142·942	1625·97	40·322
⅝	143·335	1634·92	40·432
¾	143·728	1643·89	40·543
⅞	144·120	1652·88	40·654
46 in.	144·513	1661·90	40·765
⅛	144·906	1670·95	40·876
¼	145·299	1680·01	40·986
⅜	145·691	1689·10	41·097
½	146·084	1698·23	41·208
⅝	146·477	1707·37	41·319
¾	146·869	1716·54	41·429
⅞	147·262	1725·73	41·540
47 in.	147·655	1734·94	41·651
⅛	148·047	1744·18	41·762
¼	148·440	1753·45	41·873
⅜	148·833	1762·73	41·983
½	149·226	1772·05	42·094
⅝	149·618	1781·39	42·205
¾	150·011	1790·76	42·316
⅞	150·404	1800·14	42·427
48 in.	150·796	1809·56	42·537
⅛	151·189	1818·99	42·648
¼	151·582	1828·46	42·759
⅜	151·974	1837·93	42·870
48½ in.	152·367	1847·45	42·980
⅝	152·760	1856·99	43·091
¾	153·153	1868·55	43·202
⅞	153·545	1876·13	43 313
49 in.	153·938	1885·74	43·423
⅛	154·331	1895·37	43·534
¼	154·723	1905·03	43·645
⅜	155·116	1914·70	43·756
½	155·509	1924·42	43·867
⅝	155·901	1934·15	43·977
¾	156·294	1943·91	44·088
⅞	156·687	1953·69	44·199
50 in.	157·080	1963·50	44·310
¼	157·865	1983·18	44·531
½	158·650	2002·96	44·753
¾	159·436	2022·84	44·974
51 in.	160·221	2042·82	45·196
¼	161·007	2062·90	45·417
½	161·792	2083·07	45·639
¾	162·577	2103·35	45·861
52 in.	163·363	2123·72	46·082
¼	164·148	2144·19	46·304
½	164·934	2164·75	46·525
¾	165·719	2185·42	46·747
53 in.	166·504	2206·18	46·968
¼	167·290	2227·05	47·190
½	168·075	2248·01	47·411
¾	168·861	2269 06	47·633
54 in.	169·646	2290·22	47·854
¼	170·431	2311·48	48·076
½	171·217	2332·83	48·298
¾	172·002	2354·28	48·519
55 in.	172·788	2375·83	48·741
¼	173·573	2397·48	48·962
½	174·358	2419·22	49·184
¾	175·144	2441·07	49·405
56 in.	175·929	2463·01	49·627
¼	176·715	2485·05	49·848
½	177·500	2507·19	50·070
¾	178·285	2529·42	50·291

Diam.	Circum.	Area.	Side of equal Square.	Diam.	Circum.	Area.	Side of equal Square.
57 in.	179·071	2551·76	50·513	67 in.	210·487	3525·66	59·375
¼	179·856	2574·19	50·735	¼	211·272	3552·01	59·597
½	180·642	2596·72	50·956	½	212·058	3578·47	59·818
¾	181·427	2619·35	51·178	¾	212·843	3605·03	60·040
58 in.	182·212	2642·08	51·399	68 in.	213·628	3631·68	60·261
¼	182·998	2664·91	51·621	¼	214·414	3658·44	60·483
½	183·783	2687·83	51·842	½	215·199	3685·29	60·704
¾	184·569	2710·85	52·064	¾	215·985	3712·24	60·926
59 in.	185·354	2733·97	52·285	69 in.	216·770	3739·28	61·147
¼	186·139	2757·19	52·507	¼	217·555	3766·43	61·369
½	186·925	2780·51	52·729	½	218·341	3793·67	61·591
¾	187·710	2803·92	52·950	¾	219·126	3821·02	61·812
60 in.	188·496	2827·44	53·172	70 in.	219·912	3848·46	62·034
¼	189·281	2851·05	53·393	¼	220·697	3875·99	62·255
½	189·066	2874·76	53·615	½	221 482	3903·63	62·477
¾	190·852	2898·56	53·836	¾	222·268	3931·36	62·968
61 in.	191·637	2922·47	54·048	71 in.	223·053	3959·20	69·920
¼	192·423	2946·47	54·279	¼	223·839	3987·13	63·141
½	193·208	2970·57	54·501	½	224·624	4015·16	63·363
¾	193·993	2994·77	54·723	¾	225·409	4043·28	63·545
62 in.	194·779	3019·07	54·944	72 in.	226·195	4071·51	63·806
¼	195·564	3043·47	55·166	¼	226·980	4099·83	64·028
½	196·350	3067·96	55·387	½	227·766	4128·25	64·249
¾	197·135	3092·56	55·609	¾	228·551	4156·77	64·471
63 in.	197·920	3117·25	55·830	73 in.	229·336	4185·39	64·692
¼	198·706	3142·04	56·052	¼	230·122	4214·11	64·914
½	199·491	3166·92	56·273	½	230·907	4242·92	65·135
¾	200·277	3191·91	56·495	¾	231·693	4271·83	65·357
64 in.	201·062	3216·99	56·716	74 in.	232·478	4300·85	65·578
¼	201·847	3242·17	56·938	¼	233·263	4329·95	65·800
½	202·633	3267·46	57·159	½	234·049	4359·16	66·022
¾	203·418	3292·83	57·381	¾	234·834	4388·47	66·243
65 in.	204·204	3318·31	57·603	75 in.	235·620	4417·87	66·465
¼	204·989	3343·88	57·824	¼	236·405	4447·37	66·686
½	205·774	3369·56	58·046	½	237·190	4476·97	66·908
¾	206·560	3395·33	58·267	¾	237·976	4506·67	67·129
66 in.	207·345	3421·20	58·489	76 in.	238·761	4536·47	67·351
¼	208·131	3447·16	58·710	¼	239·547	4566·36	67·572
½	208·916	3473·23	58·932	½	240·332	4596·35	67·794
¾	209·701	3499·39	59·154	¾	241·117	4626·44	68·016

Diam.	Circum.	Area.	Side of equal Square.
77 in.	241·903	4656·63	68·237
¼	242·688	4686·92	68·459
½	243·474	4717·30	68·680
¾	244·259	4747·79	68·902
78 in.	245·044	4778·37	69·123
¼	245·830	4809·05	69·345
½	246·615	4839·83	69·566
¾	247·401	4870·70	69·788
79 in.	248·186	4901·68	70·009
¼	248·971	4932·75	70·231
½	249·757	4963·92	70·453
¾	250·542	4995·19	70·674
80 in.	251·328	5026·56	70·896
½	252·898	5089·58	71·339
81 in.	254·469	5153·00	71·782
½	256·040	5216·82	72·225
82 in.	257·611	5281·02	72·668
½	259·182	5345·62	73·111
83 in.	260·752	5410·62	73·554
½	262·323	5476·00	73·997
84 in.	263·894	5541·78	74·440
½	265·465	5607·95	74·884
85 in.	267·036	5674·51	75·327
½	268·606	5741·47	75·770
86 in.	270·177	5808·81	76·213
½	271·748	5876·55	76·656
87 in.	273·319	5944·69	77·099
½	274·890	6013·21	77·542
88 in.	276·460	6082·13	77·985
½	278·031	6151·44	78·428
89 in.	279·602	6221·15	78·871
½	281·173	6291·25	79·315
90 in.	282·744	6361·74	79·758
½	284·314	6432·62	80·201
91 in.	285·885	6503·89	80·644
½	287·456	6573·56	81·087
92 in.	289·027	6647·62	81·530
½	290·598	6720·07	81·973

Diam.		Circum.		Area.	Side of equal Square.	
93 in.		292·168		6792·92	82·416	
½		293·739		6866·16	82·859	
94 in.		295·310		6939·79	83·302	
½		296·881		7013·81	83·746	
95 in.		298·452		7088·23	84·189	
½		300·022		7163·04	84·632	
feet.	in.	feet.	in.	feet.	feet.	in.
8		25	1½	50·265	7	0⅛
	1	25	4⅝	51·317	7	1¾
	2	25	7⅞	52·381	7	2⅞
	3	25	11	53·456	7	3¾
	4	26	2⅛	54·541	7	4⅝
	5	26	5¼	55·637	7	5½
	6	26	8⅜	56·745	7	6⅜
	7	26	11½	57·862	7	7¼
	8	27	2¾	58·992	7	8⅛
	9	27	5¾	60·132	7	9⅛
	10	27	9	61·282	7	9⅞
	11	28	0⅛	62·444	7	10¾
9		28	3¼	63·617	7	11⅝
	1	28	6⅜	64·800	8	0½
	2	28	9½	65·995	8	1½
	3	29	0⅝	67·200	8	2⅜
	4	29	3⅞	68·416	8	3¼
	5	29	7	69·644	8	4⅛
	6	29	10⅛	70·882	8	5
	7	30	1¼	72·130	8	5⅞
	8	30	4⅜	73·391	8	6¾
	9	30	7½	74·662	8	7⅝
	10	30	11⅝	75·943	8	8½
	11	31	1⅞	77·236	8	9½
10		31	5	78·540	8	10¼
	1	31	8⅛	79·854	8	11⅛
	2	31	11¼	81·179	9	0⅛
	3	32	2⅜	82·516	9	1
	4	32	5½	83·862	9	1⅞
	5	32	8⅝	85·221	9	2¾
	6	32	11¾	86·590	9	3⅝
	7	33	2⅞	87·969	9	4½
	8	33	6⅛	89·360	9	5⅜
	9	33	9¼	90·762	9	6¼
	10	34	0⅜	92·174	9	7⅛
	11	34	3½	93·598	9	8⅛

Diam.		Circum.		Area.	Side of equal Square.	
feet.	in.	feet.	in.	feet.	feet.	in.
11		34	6⅝	95·033	9	8⅞
	1	34	9⅞	96·478	9	9⅞
	2	35	0⅞	97·934	9	10¾
	3	35	4⅛	99·402	9	11⅝
	4	35	7¼	100·879	10	0½
	5	35	10⅜	102·368	10	1⅜
	6	36	1½	103·869	10	2¼
	7	36	4⅝	105·379	10	3⅛
	8	36	7¾	106·901	10	4
	9	36	10⅞	108·434	10	5
	10	37	2⅛	109·977	10	5⅞
	11	37	5¼	111·531	10	6¾
12		37	8⅜	113·097	10	7⅝
	1	37	11½	114·673	10	8½
	2	38	2⅝	116·260	10	9⅜
	3	38	5¾	117·859	10	10¼
	4	38	8⅞	119·467	10	11⅛
	5	39	0	121·087	11	0
	6	39	3¼	122·718	11	0⅞
	7	39	6⅜	124·359	11	1⅞
	8	39	9½	126·012	11	2¾
	9	40	0⅝	127·676	11	3⅝
	10	40	3¾	129·350	11	4½
	11	40	6⅞	131·036	11	5⅜
13		40	10	132·732	11	6¼
	1	41	1¼	134·439	11	7⅛
	2	41	4⅜	136·157	11	8⅛
	3	41	7½	137·886	11	8⅞
	4	41	10⅝	139·626	11	9¾
	5	42	1¾	141·377	11	10⅝
	6	42	4⅞	143·139	11	11⅝
	7	42	8	144·911	12	0½
	8	42	11¼	146·694	12	1⅜
	9	43	2⅜	148·489	12	2¼
	10	43	5½	150·294	12	3⅛
	11	43	8⅝	152·110	12	4
14		43	11¾	153·938	12	4⅞
	1	44	2⅞	155·775	12	5¾
	2	44	6	157·625	12	6⅝
	3	44	9¼	159·485	12	7½
	4	45	0⅜	161·355	12	8⅜
	5	45	3½	163·237	12	9⅜
	6	45	6⅝	165·130	12	10¼
	7	45	9¾	167·033	12	11⅛
	8	46	0⅞	168·947	13	0

Diam.		Circum.		Area.	Side of equal Square.	
feet.	in.	feet.	in.	feet.	feet.	in.
14	9	46	4	170·873	13	1⅛
	10	46	7¼	172·809	13	1¾
	11	46	11⅜	174·756	13	2⅝
15		47	1½	176·715	13	3½
	1	47	4⅝	178·683	13	4⅜
	2	47	7¾	180·663	13	5¼
	3	47	10⅞	182·654	13	6⅛
	4	48	2⅛	184·655	13	7⅛
	5	48	5¼	186·668	13	8
	6	48	8⅜	188·692	13	8⅞
	7	48	11½	190·726	13	9¾
	8	49	2⅝	192·771	13	10⅝
	9	49	5¾	194·828	13	11½
	10	49	8⅞	196·894	14	0⅜
	11	50	0	198·973	14	1¼
16		50	3⅛	201·062	14	2⅛
	1	50	6⅜	203·161	14	3
	2	50	9½	205·272	14	3⅞
	3	51	0⅝	207·394	14	4⅞
	4	51	3¾	209·526	14	5¾
	5	51	6⅞	211·670	14	6⅝
	6	51	10	213·825	14	7½
	7	52	1⅛	215·989	14	8⅜
	8	52	4¼	218·166	14	9¼
	9	52	7½	220·353	14	10⅛
	10	52	10⅝	222·551	14	11
	11	53	1¾	224·760	14	11⅞
17		53	4⅞	226·980	15	0¾
	1	53	8	229·210	15	1⅝
	2	53	11⅛	231·452	15	2⅝
	3	54	2¼	233·705	15	3½
	4	54	5⅜	235·968	15	4⅜
	5	54	8½	238·243	15	5¼
	6	54	11¾	240·528	15	6⅛
	7	55	2⅞	242·824	15	7
	8	55	6	245·131	15	7⅞
	9	55	9⅛	247·450	15	8¾
	10	56	0¼	249·778	15	9⅝
	11	56	3½	252·118	15	10½
18		56	6½	254·469	15	11⅜
	1	56	9¾	256·830	16	0⅜
	2	57	0⅞	259·203	16	1¼
	3	57	4	261·587	16	2⅛
	4	57	7⅛	263·980	16	3⅛
	5	57	10¼	266·386	16	3⅞
	6	58	1⅜	268·803	16	4¾

Diam.		Circum.		Area.	Side of equal Square.		Diam.		Circum.		Area.	Side of equal Square.	
feet.	in.	feet.	in.	feet.	feet.	in.	feet.	in.	feet.	in.	feet.	feet.	in.
18	7	58	4⅝	271·229	16	5⅝	22	3	69	10¾	388·822	19	8⅝
	8	58	7¾	273·667	16	6½		4	70	1⅞	391·738	19	9½
	9	58	10⅞	276·117	16	7⅜		5	70	5	394·668	19	10⅜
	10	59	2	278·576	16	8¼		6	70	8¼	397·608	19	11¼
	11	59	5⅛	281·047	16	9⅛		7	70	11⅜	400·558	20	0⅛
19		59	8¼	283·529	16	10		8	71	2½	403·520	20	1⅛
	1	59	11½	286·021	16	11		9	71	5⅝	406·493	20	2
	2	60	2½	288·524	16	11⅞		10	71	8¾	409·475	20	2⅞
	3	60	5¾	291·039	17	0¾		11	71	11⅞	412·470	20	3¾
	4	60	8¾	293·564	17	1⅝	23		72	3	415·476	20	4½
	5	60	11⅞	296·110	17	2½		1	72	6⅛	418·491	20	5½
	6	61	3⅛	298·648	17	3⅜		2	72	9⅜	421·519	20	6⅜
	7	61	6¼	301·205	17	4¼		3	73	0½	424·557	20	7¼
	8	61	9½	303·774	17	5⅛		4	73	3⅝	427·605	20	8⅛
	9	62	0½	306·355	17	6		5	73	6¾	430·665	20	9⅛
	10	62	3⅝	308·944	17	7		6	73	9⅞	433·737	20	10
	11	62	6¾	311·546	17	7⅞		7	74	1	436·817	20	10⅞
20		62	9⅞	314·160	17	8⅝		8	74	4⅛	439·910	20	11¾
	1	63	1⅛	316·782	17	9⅝		9	74	7¼	443.014	21	0⅝
	2	63	4¼	319·417	17	10½		10	74	10½	446·127	21	1½
	3	63	7⅜	322·063	17	11⅜		11	75	1⅝	449·253	21	2⅜
	4	63	11½	324·718	18	0¼	24		75	4¾	452·390	21	3¼
	5	64	1⅝	327·385	18	1⅛		1	75	7⅞	455·536	21	4⅛
	6	64	4¾	330·064	18	2		2	75	11	458·694	21	5
	7	64	7⅞	332·752	18	2⅞		3	76	2⅛	461·864	21	6
	8	64	11	335·452	18	3¾		4	76	5¼	465·042	21	6⅞
	9	65	2¼	338·163	18	4¾		5	76	8½	468·234	21	7⅝
	10	65	5⅜	340·884	18	5⅝		6	76	11⅝	471·436	21	8½
	11	65	8½	343·617	18	6½		7	77	2¾	474·647	21	9½
21		65	11⅝	346·361	18	7¼		8	77	5⅞	477·871	21	10⅜
	1	66	2¾	349·114	18	8¼		9	77	9	481·106	21	11¼
	2	66	5⅞	351·880	18	9⅛		10	78	0⅛	484·350	22	0⅛
	3	66	9	354·657	18	10		11	78	3¼	487·607	22	1
	4	67	0¼	357·443	18	10⅞	25		78	6½	490·875	22	1⅞
	5	67	3⅜	360·241	18	11¾		1	78	9⅝	494·151	22	2¾
	6	67	6½	363·051	19	0⅝		2	79	0¾	497·441	22	3⅝
	7	67	9⅝	365·869	19	1⅝		3	79	3⅞	500·741	22	4½
	8	58	0¾	368·701	19	2½		4	79	7⅛	504·051	22	5½
	9	68	3⅞	371·543	19	3⅜		5	79	11¼	507·373	22	6⅜
	10	68	7	374·394	19	4⅛		6	80	1¼	510·706	22	7¼
	11	68	10¼	377·258	19	5⅛		7	80	4½	514·048	22	8⅛
22		69	1⅜	380·133	19	5⅞		8	80	7⅝	517·403	22	9
	1	69	4½	383·017	19	6⅞		9	80	10¾	520·769	22	9⅞
	2	69	7¾	385·914	19	7¾		10	81	1⅞	524·144	22	10¾
								11	81	5	527·531	22	11⅝

Use of the Above Table.—To find, by inspection, the area of any circle, from ½ to 100 inches, of which the diameter is given:—Calling the diameters feet, the area will be feet; if rods, or yards, the area will be of a corresponding denomination.

TABLE

Of Squares, Cubes, Square and Cube Roots of Numbers.

Number.	Square.	Cube.	Square Root.	Cube Root.
1	1	1	1·0	1·0
2	4	8	1·414213	1·25992
3	9	27	1·732050	1·44225
4	16	64	2·0	1·58740
5	25	125	2·236068	1·70997
6	36	216	2·449489	1·81712
7	49	343	2·645751	1·91293
8	64	512	2·828427	2·0
9	81	729	3·0	2·08008
10	100	1000	3·162277	2·15443
11	121	1331	3·316624	3·22398
12	144	1728	3·464101	2·28942
13	169	2197	3·605551	2·35133
14	196	2744	3·741657	2·41014
15	225	3375	3·872983	2·46621
16	256	4096	4·0	2·51984
17	289	4913	4·123105	2·57128
18	324	5832	4·242640	2·62074
19	361	6859	4·358898	2·66840
20	400	8000	4·472136	2·71441
21	441	9261	4·582575	2·75892
22	484	10648	4·690415	2·80203
23	529	12167	4·795831	2·84386
24	576	13824	4·898979	2·88449
25	625	15625	5·0	2·92401
26	676	17576	5·099019	2·96249
27	729	19683	5·196152	3·0
28	784	21952	5·291502	3·03658
29	841	24389	5·385164	3·07231
30	900	27000	5·477225	3·10723
31	961	29791	5·567764	3·14138
32	1024	32768	5·656854	3·17480
33	1089	35937	5·744562	3·20753
34	1156	39304	5·830951	3·23961
35	1225	42875	5·916079	3·27106
36	1296	46656	6·0	3·30192
37	1369	50653	6·082762	3·33222
38	1444	54872	6·164414	3·36197
39	1521	59319	6·244998	3·39121
40	1600	64000	6·324555	3·41995
41	1681	68921	6·403124	3·44821
42	1764	74088	6·480740	3·47602
43	1849	79507	6·557438	3·50339
44	1936	85184	6·633249	3·53034
45	2025	91125	6·708203	3·55689
46	2116	97336	6·782330	3·58304
47	2209	103823	6·855654	3·60882
48	2304	110592	6·928303	3·63424
49	2401	117649	7·0	3·65930

Number.	Square.	Cube.	Square Root.	Cube Root.
50	2500	125000	7·071067	3·68403
51	2601	132651	7·141428	3·70843
52	2704	140608	7·211102	3·73251
53	2809	148877	7·280109	3·75628
54	2916	157464	7·348469	3·77976
55	3025	166375	7·416198	3·80295
56	3136	175616	7·483314	3·82586
57	3249	185193	7·549834	3·84850
58	3364	195112	7·615773	3·87087
59	3481	205379	7·681145	3·89299
60	3600	216000	7·745966	3·91486
61	3721	226981	7·810249	3·93649
62	3844	238328	7·874007	3·95789
63	3969	250047	7·937253	3·97905
64	4096	262144	8·0	4·0
65	4225	274625	8·062257	4·02072
66	4356	287496	8·124038	4·04124
67	4489	300763	8·185352	4·06154
68	4624	314432	8·246211	4·08165
69	4761	328509	8·306623	4·10156
70	4900	343000	8·366600	4·12128
71	5041	357911	8·426149	4·14081
72	5184	373248	8·485281	4·16016
73	5329	389017	8·544003	4·17933
74	5476	405224	8·602325	4·19833
75	5625	421875	8·660254	4·21716
76	5776	438976	8·717797	4·23582
77	5929	456533	8·774964	4·25432
78	6084	474552	8·831760	4·27265
79	6241	493039	8·888194	4·29084
80	6400	512000	8·944271	4·30887
81	6561	531441	9·0	4·32674
82	6724	551368	9·055385	4·34448
83	6889	571787	9·110433	4·36207
84	7056	592704	9·165151	4·37951
85	7225	614125	9·219544	4·39683
86	7396	636056	9·273618	4·41400
87	7569	658503	9·327379	4·43104
88	7744	681472	9·380831	4·44796
89	7921	704969	9·433981	4·46474
90	8100	729000	9·486833	4·48140
91	8281	753571	9·539392	4·49794
92	8464	778688	9·591663	4·51435
93	8649	804357	9·643650	4·53065
94	8836	830584	9·695359	4·54683
95	9025	857375	9·746794	4·56290
96	9216	884736	9·797959	4·57785
97	9409	912673	9·848857	4·59470
98	9604	941192	9·899494	4·61043

Number.	Square.	Cube.	Square Root.	Cube Root.
99	9801	970299	9·949874	4·62606
100	10000	1000000	10·0	4·64158
101	10201	1030301	10·049875	4·65701
102	10404	1061208	10·099504	4·67233
103	10609	1092727	10·148891	4·68754
104	10816	1124864	10·198039	4·70266
105	11025	1157625	10·246950	4·71769
106	11236	1191016	10·295630	4·73262
107	11449	1225043	10·344080	4·74745
108	11664	1259712	10·392304	4·76220
109	11881	1295029	10·440306	4·77685
110	12100	1331000	10·488088	4·79142
111	12321	1367631	10·535653	4·80589
112	12544	1404928	10·583005	4·82028
113	12769	1442897	10·630145	4·83458
114	12996	1481544	10·677078	4·84880
115	13225	1520875	10·723805	4·86294
116	13456	1560896	10·770329	4·87699
117	13689	1601613	10·816653	4·89097
118	13924	1643032	10·862780	4·94086
119	14161	1685159	10·908712	4·91868
120	14400	1728000	10·954451	4·93242
121	14641	1771561	11·0	4·94608
122	14884	1815848	11·045361	4·95968
123	15129	1860867	11·090536	4·97319
124	15376	1906624	11·135528	4·98663
125	15625	1953125	11·180339	5·0
126	15876	2000376	11·224972	5·01329
127	16129	2048383	11·269427	5·02652
128	16384	2097152	11·313708	5·03968
129	16641	2146689	11·357816	5·05277
130	16900	2197000	11·401754	5·06579
131	17161	2248091	11·445523	5·07875
132	17424	2299968	11·489125	5·09164
133	17689	2352637	11·532562	5·10446
134	17956	2406104	11·575836	5·11723
135	18225	2460375	11·618950	5·12992
136	18496	2515456	11·661903	5·14256
137	18769	2571353	11·704699	5·15513
138	19044	2628072	11·747344	5·16764
139	19321	2685619	11·789826	5·18010
140	19600	2744000	11·832159	5·19249
141	19881	2803221	11·874342	5·20482
142	20164	2863288	11·916375	5·21710
143	20449	2924207	11·958260	5·22932
144	20736	2985984	12·0	5·24148
145	21025	3048625	12·041594	5·25358
146	21316	3112136	12·083046	5·26563
147	21609	3176523	12·124355	5·27763
148	21904	3241792	12·165525	5·28957

Number.	Square.	Cube.	Square Root.	Cube Root.
149	22201	3307949	12·206555	5·30145
150	22500	3375000	12·247448	5·31320
151	22801	3442951	12·288205	5·32507
152	23104	3511808	12·328828	5·33680
153	23409	3581577	12·369316	5·34848
154	23716	3652264	12·409673	5·36010
155	24025	3723875	12·449899	5·37168
156	24336	3796416	12·489996	5·38323
157	24649	3869893	12·529964	5·39469
158	24964	3944312	12·569805	5·40612
159	25281	4019679	12·609520	5·41750
160	25600	4096000	12·649110	5·42883
161	25921	4173281	12·688577	5·44012
162	26244	4251528	12·727922	5·45136
163	26569	4330747	12·767145	5 46255
164	26896	4410944	12·806248	5·47370
165	27225	4492125	12·845232	5·48480
166	27556	4574296	12·884098	5·49586
167	27889	4657463	12·922848	5·50687
168	28224	4741632	12·961481	5·51784
169	28561	4826809	13·0	5·52877
170	28900	4913000	13·038404	5·53965
171	29241	5000211	13·076696	5·55049
172	29584	5088448	13·114877	5·56129
173	29929	5177717	13·152946	5·57205
174	30276	5268024	13·190906	5·58277
175	30625	5359375	13·228756	5·59344
176	30976	5451776	13·266499	5·60407
177	31329	5545233	13·304134	5·61467
178	31684	5639752	13 341664	5·62522
179	32041	5735339	13·379088	5·63574
180	32400	5832000	13·416407	5·64621
181	32761	5929741	13·453624	5·65665
182	33124	6028568	13·490737	5·66705
183	33489	6128487	13·527749	5·67741
184	33856	6229504	13·564660	5·68773
185	34225	6331625	13·601470	5·69801
186	34596	6434856	13·638181	5·70826
187	34969	6539203	13·674794	5·71847
188	35344	6644672	13·711309	5·72865
189	35721	6751269	13·747727	5·73879
190	36100	6859000	13·784048	5·74889
191	36481	6967871	13·820275	5·75896
192	36864	7077888	13·856406	5·76899
193	37249	7189057	13·892444	5·77899
194	37636	7301384	13·928388	5·78896
195	38025	7414875	13·964240	5·79889
196	38416	7529536	14·0	5·80878
197	38809	7645373	14·035668	5·81864
198	39204	7762392	14·071247	5·82847

Number.	Square.	Cube.	Square Root.	Cube Root.
199	39601	7880599	14·106736	5·83827
200	40000	8000000	14·142135	5·84803
201	40401	8120601	14·177446	5·85776
202	40804	8242408	14·212670	5·86746
203	41209	8365427	14·247806	5·87713
204	41616	8489664	14·282856	5·88676
205	42025	8615125	14·317821	5·89636
206	42436	8741816	14·352700	5·90594
207	42849	8869743	14·387494	5·91548
208	43264	8998912	14·422205	5·92499
209	43681	9123329	14·456832	5·93447
210	44100	9261000	14·491376	5·94391
211	44521	9393931	14·525839	5·95334
212	44944	9528128	14·560219	5·96273
213	45369	9663597	14·594519	5·97209
214	45796	9800344	14·628738	5·98142
215	46225	9938375	14·662878	5·99072
216	46656	10077696	14·696938	6·0
217	47089	10218313	14·730919	6·00924
218	47524	10360232	14·764823	6·01836
219	47961	10503459	14·798648	6·02765
220	48400	10648000	14·832397	6·03681
221	48841	10793861	14·866068	6·04594
222	49284	10941048	14·899664	6·05504
223	49729	11089567	14·933184	6·06412
224	50176	11239424	15·966629	6·07317
225	50625	11390625	15·0	6·08220
226	51076	11543176	15·033296	6·09119
227	51529	11697083	15·066519	6·10017
228	51984	11852352	15·099668	6·10911
229	52441	12008989	15·132746	6·11803
230	52900	12167000	15·165750	6·12692
231	53361	12326391	15·198684	6·13579
232	53824	12487168	15·231546	6·14463
233	54289	12649337	15·264337	6·15344
234	54756	12812904	15·297058	6·16223
235	55225	12977875	15·329709	6·17100
236	55696	13144256	15·362291	6·17974
237	56169	13312053	15·394804	6·18846
238	56644	13481272	15·427248	6·19715
239	57121	13651919	15·459624	6·20582
240	57600	13824000	15·491933	6·21446
241	58081	13997521	15·524174	6·22308
242	58564	14172488	15·556349	6·23167
243	59049	14348907	15·588457	6·24025
244	59536	14526784	15·620499	6·24880
245	60025	14706125	15·652475	6·25732
246	60516	14886936	15·684387	6·26582
247	61009	15069223	15·716233	6·27430
248	61504	15252992	15·748015	6·28276

Number	Square.	Cube.	Square Root.	Cube Root.
249	62001	15438249	15·779733	6·29119
250	62500	15625000	15·811388	6·29960
251	63001	15813251	15·842979	6·30799
252	63504	16003008	15·874507	6·31635
253	64009	16194277	15·905973	6·32470
254	64516	16387064	15·937377	6·33302
255	65025	16581375	15·968719	6·34132
256	65536	16777216	16·0	6·34960
257	66049	16974593	16·031219	6·35785
258	66564	17173512	16·062378	6·36609
259	67081	17373979	16·093476	6·37431
260	67600	17576000	16·124515	6·38250
261	68121	17779581	16·155494	6·39067
262	68644	17984728	16·186414	6·39882
263	69169	18191447	16·217274	6·40695
264	69696	18399744	16·248076	6·41506
265	70225	18609625	16·278820	6·42315
266	70756	18821096	16·309506	6·43122
267	71289	19034163	16·340134	6·43927
268	71824	19248832	16·370705	6·44730
269	72361	19465109	16·401219	6·45531
270	72900	19683000	16·431676	6·46330
271	73441	19902511	16·462077	6·47127
272	73984	20123648	16·492422	6·47922
273	74529	20346417	16·522711	6·48715
274	75076	20570824	16·552945	6·49506
275	75625	20796875	16·583124	6·50295
276	76176	21024576	16·613247	6·51082
277	76729	21253933	16·643317	6·51868
278	77284	21484952	16·673332	6·52651
279	77841	21717639	16·703293	6·53433
280	78400	21952000	16·733200	6·54213
281	78961	22188041	16·763054	6·54991
282	79524	22425768	16·792855	6·55767
283	80089	22665187	16·822603	6·56541
284	80656	22906304	16·852299	6·57313
285	81225	23149125	16·881943	6·58084
286	81796	23393656	16·911534	6·58853
287	82369	23639903	16·941074	6·59620
288	82944	23887872	16·970562	6·60385
289	83521	24137569	17·0	6·61148
290	84100	24389000	17·029386	6·61910
291	84681	24642171	17·058722	6·62670
292	85264	24897088	17·088007	6·63428
293	85849	25153757	17·117242	6·64185
294	86436	25412184	17·146428	6·64939
295	87025	25672375	17·175564	6·65693
296	87616	25934336	17·204650	6·66444
297	88209	26198073	17·233687	6·67194
298	88804	26463592	17·262676	6·67941

Number.	Square.	Cube.	Square Root.	Cube Root.
299	89401	26730899	17·291616	6·68688
300	90000	27000000	17·320508	6·69432
301	90601	27270901	17·349351	6·70175
302	91204	27543608	17·378147	6·70917
303	91809	27818127	17·406895	6·71656
304	92416	28094464	17·435595	6·72395
305	93025	28372625	17·464249	6·73131
306	93636	28652616	17·492855	6·73866
307	94249	28934443	17·521415	6·74599
308	94864	29218112	17·549928	6·75331
309	95481	29503629	17·578395	6·76061
310	96100	29791000	17·606816	6·76789
311	96721	30080231	17·635192	6·77516
312	97344	30371328	17·663521	6·78242
313	97969	30664297	17·691806	6·78966
314	98596	30959144	17·720045	6·79688
315	99225	31255875	17·748239	6·80409
316	99856	31554496	17·776388	6·81128
317	100489	31855013	17·804493	6·81846
318	101124	32157432	17·832554	6·82562
319	101761	32461759	17·860571	6·83277
320	102400	32768000	17·888543	6·83990
321	103041	33076161	17·916472	6·84702
322	103684	33386248	17·944358	6·85412
323	104329	33698267	17·972200	6·86121
324	104976	34012224	18·0	6·86828
325	105625	34328125	18·027756	6·87534
326	106276	34645976	18·055470	6·88238
327	106929	34965783	18·083141	6·88941
328	107584	35287552	18·110770	6·89643
329	108241	35611289	18·138357	6·90343
330	108900	35937000	18·165902	6·91042
331	109561	36264691	18·193405	6·91739
332	110224	36594368	18·220867	6·92435
333	110889	36926037	18·248287	6·93130
334	111556	37259704	18·275666	6·93823
335	112225	37595375	18·303005	6·94514
336	112896	37933056	18·330302	6·95205
337	113569	38272753	18·357559	6·95894
338	114244	38614472	18·384776	6·96581
339	114921	38958219	18·411952	6·97268
340	115600	39304000	18·439088	6·97953
341	116281	39651821	18·466185	6·98636
342	116964	40001688	18·493242	6·99319
343	117649	40353607	18·520259	7·0
344	118336	40707584	18·547237	7·00679
345	119025	41063625	18·574175	7·01357
346	119716	41421736	18·601075	7·02034
347	120409	41781923	18·627936	7·02710
348	121104	42144192	18·654758	7·03385

Number.	Square.	Cube.	Square Root.	Cube Root.
349	121801	42508549	18·681541	7·04058
350	122500	42875000	18·708286	7·04720
351	123201	43243551	18·734994	7·05400
352	123904	43614208	18·761663	7·06069
353	124609	43986977	18·788294	7·06737
354	125316	44361864	18·814887	7·07404
355	126025	44738875	18·841443	7·08069
356	126736	45118016	18·867962	7·08734
357	127449	45499293	18·894443	7·09397
358	128164	45882712	18·920887	7·10058
359	128881	46268279	18·947295	7·10719
360	129600	46656000	18·973666	7·11378
361	130321	47045881	19·0	7·12036
362	131044	47437928	19·026297	7·12693
363	131769	47832147	19·052558	7·13349
364	132496	48228544	19·078784	7·14003
365	133225	48627125	19·104973	7·14656
366	133956	49027896	19·131126	7·15309
367	134689	49430863	19·157244	7·15959
368	135424	49836032	19·183326	7·16609
369	136161	50243409	19·209372	7·17258
370	136900	50653000	19·235384	7·17905
371	137641	51064811	19·261360	7·18551
372	138384	51478848	19·287301	7·19196
373	139129	51895117	19·313207	7·19840
374	139876	52313624	19·339079	7·20483
375	140625	52734375	19·364916	7·21124
376	141376	53157376	19·390719	7·21765
377	142129	53582633	19·416487	7·22404
378	142884	54010152	19·442222	7·23042
379	143641	54439939	19·467922	7·23679
380	144400	54872000	19·493588	7·24315
381	145161	55306341	19·519221	7·24950
382	145924	55742968	19·544820	7·25584
383	146689	56181887	19·570385	7·26216
384	147456	56623104	19·595917	7·26848
385	148225	57066625	19·621416	7·27478
386	148996	57512456	19·646882	7·28107
387	149769	57960603	19·672315	7·28736
388	150544	58411072	19·697715	7·29363
389	151321	58863869	19·723082	7·29989
390	152100	59319000	19·748417	7·30614
391	152881	59776471	19·773719	7·31238
392	153664	60236288	19·798989	7·31861
393	154449	60698457	19·824227	7·32482
394	155236	61162984	19·849433	7·33103
395	156025	61629875	19·874606	7·33723
396	156816	62099136	19·899748	7·34342
397	157609	62570773	19·924858	7·34959
398	158404	63044792	19·949937	7·35576

Number.	Square.	Cube.	Square Root.	Cube Root.
399	159201	63521199	19·974984	7·36191
400	160000	64000000	20·0	7·36806
401	160801	64481201	20·024984	7·37419
402	161604	64964808	20.049937	7·38032
403	162409	65450827	20·074859	7·38643
404	163216	65939264	20·099751	7·39254
405	164025	66430125	20·124611	7·39863
406	164836	66923416	20·149441	7·40472
407	165649	67419143	20·174241	7·41079
408	166464	67917312	20·199009	7·41685
409	167281	68417929	20·223748	7·42291
410	168100	68921000	20·248456	7·42895
411	168921	69426531	20·273134	7·43499
412	169744	69934528	20·297783	7·44101
413	170569	70444997	20·322401	7·44703
414	171396	70951944	20·346980	7·45303
415	172225	71473375	20·371548	7·45903
416	173056	71991296	20·396078	7·46502
417	173889	72511713	20·420577	7·47099
418	174724	73034632	20·445048	7·47696
419	175561	73560059	20·469489	7·48292
420	176400	74088000	20·493901	7·48887
421	177241	74618461	20·518284	7·49481
422	178084	75151448	20·542638	7·50074
423	178929	75686967	20·566963	7·50666
424	179776	76225024	20·591260	7·51257
425	180625	76765625	20·615528	7·51847
426	181476	77308776	20·639767	7·52436
427	182329	77854483	20·663978	7·53024
428	183184	78402752	20·688160	7·53612
429	184041	78953589	20·712315	7·54198
430	184900	79507000	20·736441	7·54784
431	185761	80062991	20·760539	7·55368
432	186624	80621568	20·784609	7·55952
433	187489	81182737	20·808652	7·56535
434	188356	81746504	20·832666	7·57117
435	189225	82312875	20·856653	7·57698
436	190096	82881856	20·880613	7·58278
437	190969	83453453	20·904545	7·58857
438	191844	84027672	20·928449	7·59436
439	192721	84604519	20·952326	7·60013
440	193600	85184000	20·976177	7·60590
441	194481	85766121	21·0	7·61166
442	195364	86350888	21·023796	7·61741
443	196249	86938307	21·047565	7·62315
444	197136	87528384	21·071307	7·62883
445	198025	88121125	21·095023	7·63460
446	198916	88716536	21·118712	7·64032
447	199809	89314623	21·142374	7·64602
448	200704	89915392	21·166010	7·65172

Number.	Square.	Cube.	Square Root.	Cube Root.
449	201601	90518849	21·189620	7·65741
450	202500	91125000	21·213204	7·66309
451	203401	91733851	21·236760	7·66876
452	204304	92345408	21·260291	7·67443
453	205209	92959677	21·283796	7·68008
454	206116	93576664	21·307275	7·68573
455	207025	94196375	21·330729	7·69137
456	207936	94818816	21·354156	7·69700
457	208849	95443993	21·377558	7·70262
458	209764	96071912	21·400934	7·70823
459	210681	96702579	21·424285	7·71384
460	211600	97336000	21·447610	7·71944
461	212521	97972181	21·470910	7·72503
462	213444	98611128	21·494185	7·73061
463	214369	99252847	21·517434	7·73618
464	215296	99897344	21·540659	7·74175
465	216225	100544625	21·563858	7·74731
466	217156	101194696	21·587033	7·75286
467	218089	101847563	21·610182	7·75840
468	219024	102503232	21·633307	7·76393
469	219961	103161709	21·656407	7·76946
470	220900	103823000	21·679483	7·77498
471	221841	104487111	21·702534	7·78049
472	222784	105154048	21·725561	7·78599
473	223729	105823817	21·748563	7·79148
474	224676	106496424	21·771541	7·79697
475	225625	107171875	21·794494	7·80245
476	226576	107850176	21·817424	7·80792
477	227529	108531333	21·840329	7·81338
478	228484	109215352	21·863211	7·81884
479	229441	109902239	21·886068	7·82429
480	230400	110592000	21·908902	7·82973
481	231361	111284641	21·931712	7·83516
482	232324	111980168	21·954498	7·84059
483	233289	112678587	21·977261	7·84601
484	234256	113379904	22·0	7·85142
485	235225	114084125	22·022715	7·85682
486	236196	114791256	22·045407	7·86222
487	237169	115501303	22·068076	7·86761
488	238144	116214272	22·090722	7·87299
489	239121	116930169	22·113344	7·87836
490	240100	117649000	22·135943	7·88373
491	241081	118370771	22·158519	7·88909
492	242064	119095488	22·181073	7·89444
493	243049	119823157	22·203603	7·89979
494	244036	120553784	22·226110	7·90512
495	245025	121287375	22·248595	7·91046
496	246016	122023936	22·271057	7·91578
497	247009	122763473	22·293496	7·92110
498	248004	123505992	22·315913	7·92640

Number.	Square.	Cube.	Square Root.	Cube Root.
499	249001	124251499	22·338307	7·93171
500	250000	125000000	22·360679	7·93700
501	251001	125751501	22·383029	7·94229
502	252004	126506008	22·405356	7·94757
503	253009	127263527	22·427661	7·95284
504	254016	128024064	22·449944	7·95811
505	255025	128787625	22·472205	7·96337
506	256036	129554216	22·494443	7·96862
507	257049	130323843	22·516660	7·97387
508	258064	131096512	22·538855	7·97911
509	259081	131872229	22·561028	7·98434
510	260100	132651000	22·583179	7·98956
511	261121	133432831	22·605309	7·99478
512	262144	134217728	22·627417	8·0
513	263169	135005697	22·649503	8·00520
514	264196	135796744	22·671568	8·01040
515	265225	136590875	22·693611	8·01559
516	266256	137388096	22·715633	8·02077
517	267289	138188413	22·737634	8·02595
518	268324	138991832	22·759613	8·03112
519	269361	139798359	22·781571	8·03629
520	270400	140608000	22·803508	8·04145
521	271441	141420761	22·825424	8·04660
522	272484	142236648	22·847319	8·05174
523	273529	143055667	22·869193	8·05688
524	274576	143877824	22·891046	8·06201
525	275625	144703125	22·912878	8·06714
526	276676	145531576	22·934689	8·07226
527	277729	146363183	22·956480	8·07737
528	278784	147197952	22·978250	8·08248
529	279841	148035889	23·0	8·08757
530	280900	148877000	23·021728	8·09267
531	281961	149721291	23·043437	8·09775
532	283024	150568768	23·065125	8·10283
533	284089	151419437	23·086792	8·10791
534	285156	152273304	23·108440	8·11298
535	286225	153130375	23·130067	8·11804
536	287296	153990656	23·151673	8·12309
537	288369	154854153	23·173260	8·12814
538	289444	155720872	23·194827	8·13318
539	290521	156590819	23·216373	8·13822
540	291600	157464000	23·237900	8·14325
541	292681	158340421	23·259406	8·14827
542	263764	159220088	23·280893	8·15329
543	294849	160103007	23·302360	8·15830
544	295936	160989184	23·323807	8·16330
545	297025	161878625	23·345235	8·16830
546	298116	162771336	23·366642	8·17330
547	299209	163667323	23·388031	8·17828
548	300304	164566592	23·409399	8·18326

Number.	Square.	Cube.	Square Root.	Cube Root.
549	301401	165469149	23·430749	8·18824
550	302500	166375000	23·452078	8·19321
551	303601	167284151	23·473389	8·19817
552	304704	168196608	23·494680	8·20313
553	305809	169112377	23·515952	8·20808
554	306916	170031464	23·537204	8·21302
555	308025	170953875	23·558438	8·21796
556	309136	171879616	23·579652	8·22289
557	310249	172808693	23·600847	8·22782
558	311364	173741112	23·622023	8·23274
559	312481	174676879	23·643180	8·23766
560	313600	175616000	23·664319	8·24257
561	314721	176558481	23·685438	8·24747
562	315844	177504328	23·706539	8·22237
563	316969	178453547	23·727621	8·25726
564	318096	179406144	23·748684	8·26214
565	319225	180362125	23·769728	8·26702
566	320356	181321496	23·790754	8·27190
567	321489	182284263	23·811761	8·27677
568	322624	183250432	23·832750	8·28163
569	323761	184220009	23·853720	8·28649
570	324900	185193000	23·874672	8·29134
571	326041	186169411	23·895606	8·29619
572	327184	187149248	23·916521	8·30103
573	328329	188132517	23·937418	8·30586
574	329476	189119224	23·958297	8·31069
575	330625	190109375	23·979157	8·31551
576	331776	191102976	24·0	8·32033
577	332929	192100033	24·020824	8·32514
578	334084	193100552	24·041630	8·32995
579	335241	194104539	24·062418	8·33475
580	336400	195112000	24·083189	8·33955
581	337561	196122941	24·103941	8·34434
582	338724	197137368	24·124676	8·34912
583	339889	198155287	24·145392	8·35390
584	341056	199176704	24·166091	8·35867
585	342223	200201625	24·186773	8·36344
586	343396	201230056	24·207436	8·36820
587	344569	202262003	24·228082	8·37296
588	345744	203297472	24·248711	8·37771
589	346921	204336469	24·269322	8·38246
590	348100	205379000	24·289915	8·38720
591	349281	206425071	24·310491	8·39194
592	350464	207474688	24·331050	8·39667
593	351649	208527857	24·351591	8·40139
594	352836	209584584	24·372115	8·40611
595	354025	210644875	24·392621	8·41083
596	355216	211708736	24·413111	8·41554
597	356409	212776173	24·433583	8·42024
598	357604	213847192	24·454038	8·42494

Number.	Square.	Cube.	Square Root.	Cube Root.
599	358801	214921799	24·474476	8·42963
600	360000	216000000	24·494897	8·43432
601	361201	217081801	24·515301	8·43900
602	362404	218167208	24·535688	8·44368
603	363609	219256227	24·556058	8·44836
604	364816	220348864	24·576411	8·45302
605	366025	221445125	24·596747	8·45768
606	367236	222545016	24·617067	8·46234
607	368449	223648543	24·637370	8·46699
608	369664	224755712	24·657656	8·47164
609	370881	225866529	24·677925	8·47628
610	372100	226981000	24·698178	8·48092
611	373321	228099131	24·718414	8·48555
612	374544	229220928	24·738633	8·49018
613	375769	230346397	24·758836	8·49480
614	376996	231475544	24·779023	8·49942
615	378225	232608375	24·799193	8·50403
616	379456	233744896	24·819347	8·50864
617	380689	234885113	24·839484	8·51324
618	381924	236029032	24·859605	8·51784
619	383161	237176659	24·879710	8·52243
620	384400	238328000	24·899799	8·52701
621	385641	239483061	24·919871	8·53160
622	386884	240641848	24·939927	8·53617
623	388129	241804367	24·959967	8·54074
624	389376	242970624	24·979992	8·54531
625	390625	244140625	25·0	8·54987
626	391876	245314376	25·019992	8·55443
627	393129	246491883	25·039968	8·55899
628	394384	247673152	25·059928	8·56353
629	395641	248858189	25·079872	8·56808
630	396900	250047000	25·099800	8·57261
631	398161	251239591	25·119713	8·57715
632	399424	252435968	25·139610	8·58168
633	400689	253636137	25·159491	8·58620
634	401956	254840104	25·179356	8·59072
635	403225	256047875	25·199206	8·59523
636	404496	257259456	25·219040	8·59974
637	405769	258474853	25·238858	8·60425
638	407044	259694072	25·258661	8·60875
639	408321	260917119	25·278449	8·61324
640	409600	262144000	25·298221	8·61773
641	410881	263374721	25·317977	8·62222
642	412164	264609288	25·337718	8·62670
643	413449	265847707	25·357444	8·63118
644	414736	267089984	25·377155	8·63565
645	416025	268336125	25·396850	8·64012
646	417316	269586136	25·416530	8·64458
647	418609	270840023	25·436194	8·64904
648	419904	272097792	25·455844	8·65349

TABLE

Of Diameters, Circumferences, and Areas of Circles, and the Contents in Gallons (of 231 Cubic Inches) at 1 Foot in Depth.

Diam.	Circum.	Area.	Gallons.	Diam.	Circum	Area.	Gallons.
	Inches.	Inches.			Inches.	Inches.	
1 in.	3·1416	·7854	·04084	6½ in.	20·420	33·183	1·72552
⅛	3·5343	·9940	·05169	⅝	20·813	34·471	1·79249
¼	3·9270	1·2271	·06380	¾	21·205	35·784	1·86077
⅜	4·3197	1·4848	·07717	⅞	21·598	37·122	1·93034
½	4·7124	1·7671	·09188	7 in.	21·991	38·484	2·00117
⅝	5·1051	2·0739	·10782	⅛	22·383	39·871	2·07329
¾	5·4978	2·4052	·12506	¼	22·776	41·282	2·14666
⅞	5·8905	2·7611	·14357	⅜	23·169	42·718	2·22134
2 in.	6·2832	3·1416	·16333	½	23·562	44·178	2·29726
⅛	6·6759	3·5465	.18439	⅝	23·954	45·633	2·37448
¼	7·0686	3·9760	·20375	¾	24·347	47·173	2·45299
⅜	7·4613	4·4302	·23036	⅞	24·740	48·707	2·53276
½	7·8540	4·9087	·25522	8 in.	25·132	50·265	2·61378
⅝	8·2467	5·4119	·28142	⅛	25·515	51·848	2·69609
¾	8·6394	5·9395	·30883	¼	25·918	53·456	2·77971
⅞	9·0321	6·4918	·33753	⅜	26·310	55·088	2·86458
3 in.	9·4248	7·0686	·33754	½	26·703	56·745	2·95074
⅛	9·8175	7·6699	·39879	⅝	27·096	58·426	3·03815
¼	10·210	8·2957	·43134	¾	27·489	60·132	3·12686
⅜	10·602	8·9462	·46519	⅞	27·881	61·832	3·21682
½	10·995	9·6211	·50029	9 in.	28·274	63·617	3·30808
⅝	11·388	10·320	·53664	⅛	28·667	65·396	3·40059
¾	11·781	11·044	·57429	¼	29·059	67·200	3·49440
⅞	12·173	11·793	·61324	⅜	29·452	69·029	3·58951
4 in.	12·566	12·566	·65343	½	29·845	70·882	3·68586
⅛	12·959	13·364	·69493	⅝	30·237	72·759	3·78347
¼	13·351	14·186	·73767	¾	30·630	74·662	3·88242
⅜	13·744	15·033	·78172	⅞	31·023	76·588	3·98258
½	14·137	15·904	·82701	10 in.	31·416	78·540	4·08408
⅝	14·529	16·800	·87360	⅛	31·808	80·515	4·18678
¾	14·922	17·720	·92144	¼	32·201	82·516	4·29083
⅞	15·315	18·665	·97058	⅜	32·594	84·540	4·39608
5 in.	15·708	19·635	1·02102	½	32·936	86·590	4·50268
⅛	16·100	20·629	1·07271	⅝	33·379	88·664	4·61053
¼	16·493	21·647	1·12564	¾	33·772	90.762	4·71962
⅜	16·886	22·690	1·17988	⅞	34·164	92·885	4·82846
½	17·278	23·758	1·23542	11 in.	34·557	95·033	4·94172
⅝	17·671	24·850	1·29220	⅛	34·950	97·205	5·05466
¾	18·064	25·967	1·35028	¼	35·343	99·402	5·16890
⅞	18·457	27·108	1·40962	⅜	35·735	101·623	5·28439
6 in.	18·849	28·274	1·47025	½	36.128	103·869	5·40119
⅛	19·242	29·464	1·53213	⅝	36.521	106·139	5.51923
¼	19·635	30·679	1·59531	¾	36.913	108·434	5.63857
⅜	20·027	31·919	1·65971	⅞	37.306	110·753	5.75916

Diam.		Circum.		Area.	Gallons.	Diam.		Circum.		Area.	Gallons.
Ft.	In.	Ft.	In.	Feet.		Ft.	In.	Ft.	In.	Feet.	
1		3	1⅝	·7854	5·8735	5		15	8½	19·6350	146·8384
1	1	3	4⅝	·9217	6·8928	5	1	15	11⅝	20·2947	151·7718
1	2	3	8	1·0690	7·9944	5	2	16	2¾	20·9656	156·7891
1	3	3	11	1·2271	9·1766	5	3	16	5¾	21·6475	161·8886
1	4	4	2⅛	1·3962	10·4413	5	4	16	9	22·3400	167·0674
1	5	4	5⅜	1·5761	11·7866	5	5	17	0⅛	23·0437	172·3300
1	6	4	8½	1·7671	13·2150	5	6	17	3¼	23·7583	177·6740
1	7	4	11⅝	1·9689	14·7241	5	7	17	6⅜	24·4835	183·0973
1	8	5	2¾	2·1816	16·3148	5	8	17	9⅝	25·2199	188·6045
1	9	5	5⅞	2·4052	17·9870	5	9	18	0¾	25·9672	194·1930
1	10	5	9	2·6398	19·7414	5	10	18	3⅞	26·7251	199·8610
1	11	6	2¼	2·8852	21·4830	5	11	18	7⅛	27·4943	205·6133
2		6	3⅜	3·1416	23·4940	6		18	10⅛	28·2744	211·4472
2	1	6	6½	3·4087	25·4916	6	3	19	7½	30·6796	229·4342
2	2	6	9⅝	3·6869	27·5720	6	6	20	4⅞	33·1831	248·1564
2	3	7	0¾	3·9760	29·7340	6	9	21	2⅜	35·7847	267·6122
2	4	7	3⅞	4·2760	32·6976	7		21	11⅞	38·4846	287·8032
2	5	7	7	4·5869	34·3027	7	3	22	9¼	41·2825	308·7270
2	6	7	10¼	4·9087	33·7092	7	6	23	6¾	44·1787	330·3859
2	7	8	1⅜	5·2413	39·1964	7	9	24	4⅛	47·1730	352·7665
2	8	8	4½	5·5850	41·7668	8		25	1½	50·2656	375·9062
2	9	8	7⅝	5·9395	44·4179	8	3	25	11	53·4562	399·7668
2	10	8	10¾	6·3049	47·1505	8	6	26	8⅜	56·7451	424·3625
2	11	9	1⅞	6·6813	49·9654	8	9	27	5¾	60·1321	449·2118
3		9	5	7·0686	52·8618	9		28	3¼	63·6174	475·7563
3	1	9	8¼	7·4666	55·8382	9	3	29	0⅝	67·2007	502·5536
3	2	9	11⅜	7·8757	58·8976	9	6	29	10⅛	70·8823	530·0861
3	3	10	2½	8·2957	62·0386	9	9	30	7½	74·6620	558·3522
3	4	10	5⅝	8·7265	65·2602	10		31	5	78·5400	587·3534
3	5	10	8¾	9·1683	68·5193	10	3	32	2⅜	82·5160	617·0876
3	6	10	11⅞	9·6211	73·1504	10	6	32	11¾	86·5903	647·5568
3	7	11	3	10·0846	75·4166	10	9	33	9¼	90·7627	678·2797
3	8	11	6⅛	10·5591	78·9652	11		34	6⅝	95·0334	710·6977
3	9	11	9⅜	11·0446	82.5959	11	3	35	4⅛	99·4021	743·3686
3	10	12	5½	11·5409	86·3074	11	6	36	1½	103·8691	776·7746
3	11	12		12·0481	90·1004	11	9	36	10⅞	108·4342	810·9143
4		12	6¾	12·5664	93·9754	12		37	8⅜	113·0976	848·1890
4	1	12	9⅞	13·0952	97·9310	12	3	38	5¾	117·8590	881·3966
4	2	13	1	13·6353	101·9701	12	6	39	3¼	122·7187	917·7395
4	3	13	4⅛	14·1862	103·0300	12	9	40	0⅝	127·6765	954·8159
4	4	13	7¼	14·7479	110·2907	13		40	10	132·7326	992·6274
4	5	13	10½	15·3206	114·5735	13	3	41	7½	137·8867	1031·1719
4	6	14	1⅝	15·9043	118·9386	13	6	42	4⅞	143·1391	1070·4514
4	7	14	4⅝	16·4986	123·3830	13	9	43	2¼	148·4896	1108·0645
4	8	14	7⅞	17.1041	127·9112	14		43	11¾	153·9384	1151·2129
4	9	14	11	17.7205	132·5209	14	3	44	9⅛	159·4852	1192·6940
4	10	15	2⅛	18.3476	137·2105	14	6	45	6⅝	165·1303	1234·9104
4	11	15	5¼	18.9858	142·0582	14	9	46	4	170·8735	1277·8615

Diam.		Circum.		Area.	Gallons.	Diam.		Circum.		Area.	Gallons.
Ft.	In.	Ft.	In.	Feet.		Ft.	In.	Ft.	In.	Feet.	
15		47	1½	176·7150	1321·5454	17		53	4⅞	226·9806	1697·4516
15	3	47	10⅞	182·6545	1365·9634	17	3	54	2⅛	233·7055	1747·7431
15	6	48	8¼	188·6923	1407·5165	17	6	54	11⅝	240·5287	1798·7698
15	9	49	5¾	194·8282	1457·0032	17	9	55	9⅛	247·4500	1850·5301
16		50	3⅛	201·0624	1503·6250	18		56	6½	254·4696	1903·0254
16	3	51	0½	207·3946	1550·9797	18	3	57	4	261·5872	1956·2537
16	6	51	10	213·8251	1599·0696	18	6	58	1⅜	268·8031	2010·2171
16	9	52	7⅜	220·3537	1647·8930	18	9	58	10¾	276·1171	2064·9140

DECIMAL EQUIVALENTS.

FRACTIONS OF A LINEAL INCH CONVERTED INTO DECIMALS.

8ths.

$\frac{1}{8}$ = .125
$\frac{1}{4}$ = .25
$\frac{3}{8}$ = .375
$\frac{1}{2}$ = .50
$\frac{5}{8}$ = .625
$\frac{3}{4}$ = .75
$\frac{7}{8}$ = .875

16ths.

$\frac{1}{16}$ = .0625
$\frac{3}{16}$ = .1875
$\frac{5}{16}$ = .3125
$\frac{7}{16}$ = .4375
$\frac{9}{16}$ = .5625
$\frac{11}{16}$ = .6875
$\frac{13}{16}$ = .8125
$\frac{15}{16}$ = .9375

32nds.

$\frac{1}{32}$ = .03125
$\frac{3}{32}$ = .09375
$\frac{5}{32}$ = .15625
$\frac{7}{32}$ = .21875
$\frac{9}{32}$ = .28125
$\frac{11}{32}$ = .34375
$\frac{13}{32}$ = .40625
$\frac{15}{32}$ = .46875
$\frac{17}{32}$ = .53125
$\frac{19}{32}$ = .59375
$\frac{21}{32}$ = .65625
$\frac{23}{32}$ = .71875
$\frac{25}{32}$ = .78125
$\frac{27}{32}$ = .84375
$\frac{29}{32}$ = .90625
$\frac{31}{32}$ = .96875

64ths.

$\frac{1}{64}$ = .015625
$\frac{3}{64}$ = .046875
$\frac{5}{64}$ = .078125
$\frac{7}{64}$ = .109375
$\frac{9}{64}$ = .140625
$\frac{11}{64}$ = .171875
$\frac{13}{64}$ = .203125
$\frac{15}{64}$ = .234375
$\frac{17}{64}$ = .265625
$\frac{19}{64}$ = .296875
$\frac{21}{64}$ = .328125
$\frac{23}{64}$ = .359375
$\frac{25}{64}$ = .390625
$\frac{27}{64}$ = .421875
$\frac{29}{64}$ = .453125
$\frac{31}{64}$ = .484375
$\frac{33}{64}$ = .515625
$\frac{35}{64}$ = .546875
$\frac{37}{64}$ = .578125
$\frac{39}{64}$ = .609375
$\frac{41}{64}$ = .640625
$\frac{43}{64}$ = .671875
$\frac{45}{64}$ = .703125
$\frac{47}{64}$ = .734375
$\frac{49}{64}$ = .765625
$\frac{51}{64}$ = .796875
$\frac{53}{64}$ = .828125
$\frac{55}{64}$ = .859375
$\frac{57}{64}$ = .890625
$\frac{59}{64}$ = .921875
$\frac{61}{64}$ = .953125
$\frac{63}{64}$ = .984375

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CONVERSION OF VULGAR FRACTIONS INTO DECIMALS.

Fractions.	Decimals.	Fractions.	Decimals.
1 : 2	.5	7 : 8	.875
1 : 3	.33333	5 : 12	.41666
2 : 3	.66666	7 : 12	.58333
1 : 4	.25	11 : 12	.925
3 : 4	.75	1 : 24	.04166
1 : 5	.2	5 : 24	.28333
3 : 5	.6	7 : 24	.29166
1 : 6	.16666	11 : 24	.45833
5 : 6	.83333	13 : 24	.54166
1 : 8	.125	17 : 24	.70833
3 : 8	.375	19 : 24	.79166
5 : 8	.625	23 : 24	.95833

CONVERSION OF FRACTIONS OF AN INCH INTO DECIMALS OF A LINEAL FOOT.

$\frac{1}{64}$ Inch = 0·001375 feet.
$\frac{1}{32}$ “ = 0·00265 “
$\frac{1}{16}$ “ = 0·005208 “
$\frac{1}{8}$ “ = 0·01041 “
$\frac{1}{4}$ “ = 0·02083 “

$\frac{3}{8}$ Inch = 0·03125 feet.
$\frac{1}{2}$ “ = 0·04166 “
$\frac{5}{8}$ “ = 0·05208 “
$\frac{3}{4}$ “ = 0·0625 “
$\frac{7}{8}$ “ = 0·07291 “

CONVERSION OF INCHES AND FRACTIONS (UP TO 12 INCHES) INTO DECIMALS OF A LINEAL FOOT.

Inches		⅛	¼	⅜	½	⅝	¾	⅞
1	.08333	.09375	.10416	.11458	.125	.13541	.14588	.15639
2	.16666	.17707	.1875	.19792	.20832	.21873	.22914	.23965
3	.25	.26041	.270	.28125	.29166	.30208	.3125	.32291
4	.33333	.34375	.35416	.364	.375	.38541	.39588	.40639
5	.41666	.42707	.437	.44792	.45832	.46873	.47914	.48965
6	.5	.51041	.520	.53125	.54166	.55208	.2625	.57291
7	.58333	.59375	.60416	.614	.625	.63541	.64588	.65639
8	.66666	.67707	.685	.69792	.70832	.71773	.72914	.73965
9	.75	.76041	.770	.78125	.79169	.80208	.8425	.82291
10	.83333	.84375	.85416	.864	.875	.88541	.89588	.90639
11	.91666	.92707	.937	.94792	.95832	.96873	.97914	.98965
12	1 foot.	foot.	foot.	foot.	foot.	foot.	foot.	foot.

CONVERSION OF INCHES INTO DECIMALS OF A LINEAL YARD.

1 inch = ·0277 yard.
2 inches = ·0555 “
3 “ = ·0833 “
4 “ = ·1111 “

5 inches = ·1389 yard.
6 “ = ·1666 “
7 “ = ·1944 “
8 “ = ·2222 “

9 inches = ·25 yard.
10 “ = ·2778 “
11 “ = ·3055 “
12 “ = ·3333 “

DECIMAL EQUIVALENTS OF POUNDS AND OUNCES AVOIRDUPOIS.

Ozs.	lbs.	Ozs.	lbs.	Ozs.	lbs.	Ozs.	lbs.	Ozs.	lbs.
¼	= ·015625	3	= ·1875	6½	= ·40625	10	= ·625	13½	= ·84375
½	= ·03125	3½	= ·21875	7	= ·4375	10½	= ·65625	14	= ·875
¾	= ·046875	4	= ·25	7½	= ·46875	11	= ·6875	14½	= ·90625
1	= ·0625	4½	= ·28125	8	= ·5	11½	= ·71875	15	= ·9375
1½	= ·09375	5	= ·3125	8½	= ·53125	12	= ·75	15½	= ·96875
2	= ·125	5½	= ·34375	9	= ·5625	12½	= ·78125	16	= ·1
2½	= ·15625	6	= ·373	9½	= ·59375	13	= ·8125	....	

SCANTLING AND TIMBER,

Accurately reduced to Inch Board Measure.

EXPLANATION.

The length of any piece of scantling, or timber, will be found in the left-hand column, under the side dimensions. The breadth and depth (or side dimensions), in inches, will be found at the head or center of each column of computations. Thus, on page 261, a piece of scantling 2½ by 11 inches, side dimension, and 16 feet long, is shown to contain 36 feet and 8 inches, of board measure. On page 263, a piece of scantling 4 by 10 inches, side dimension, and 17 feet long, is shown to contain 56 feet 8 inches of board measure. The answer sought for, in all cases, will be found directly on the right of the length, and under the side dimensions. If a piece of scantling, or stick of timber, should exceed in length any provision which has been made in these tables, its contents would be shown by taking twice what is shown for half its length. Thus, a stick of timber, or piece of scantling, 46 feet long, would contain twice as many feet, board measure, as is shown in the table to be the contents of a stick 23 feet long. So also, one 39 feet long would contain as many feet, board measure, as these tables show opposite to 22 and 17 feet long, or 3 times the contents of one 13 feet long.

TABLES.

2 by 2.		2 by 3.		2 by 4.		2 by 5.		2 by 6.		2 by 7.	
Length.		Length.		Length.		Length.		Length.		Length.	
1	0·4	1	0·6	1	0·8	1	0·10	1	1·	1	1·2
2	0·8	2	1·	2	1·4	2	1·8	2	2·	2	2·4
3	1·	3	1·6	3	2·	3	2·6	3	3·	3	3·6
4	1·4	4	2·	4	2·8	4	3·4	4	4·	4	4·8
5	1·8	5	2·6	5	3·4	5	4·2	5	5·	5	5·10
6	2·	6	3·	6	4·	6	5·	6	6·	6	7·
7	2·4	7	3·6	7	4·8	7	5·10	7	7·	7	8·2
8	2·8	8	4·	8	5·4	8	6·8	8	8·	8	9·4
9	3·	9	4·6	9	6·	9	7·6	9	9·	9	10·6
10	3·4	10	5·	10	6·8	10	8·4	10	10·	10	11·8
11	3·8	11	5·6	11	7·4	11	9·2	11	11·	11	12·10
12	4·	12	6·	12	8·	12	10·	12	12·	12	14·
13	4·4	13	6·6	13	8·8	13	10·10	13	13·	13	15·2
14	4·8	14	7·	14	9·4	14	11·8	14	14·	14	16·4
15	5·	15	7·6	15	10·	15	12·6	15	15·	15	17·6
16	5·4	16	8·	16	10·8	16	13·4	16	16·	16	18·8
17	5·8	17	8·6	17	11·4	17	14·2	17	17·	17	19·10
18	6·	18	9·	18	12·	18	15·	18	18·	18	21·
19	6·4	19	9·6	19	12·8	19	15·10	19	19·	19	22·2
20	6·8	20	10·	20	13·4	20	16·8	20	20·	20	23·4
21	7·	21	10·6	21	14·	21	17·6	21	21·	21	24·6
22	7·4	22	11·	22	14·8	22	18·4	22	22·	22	25·8
23	7·8	23	11·6	23	15·4	23	19·2	23	23·	23	26·10
24	8·	24	12·	24	16·	24	20·	24	24·	24	28·

Length.	2 by 8.	2 by 9.	2 by 10.	2 by 11.	2½ by 5.	2½ by 6.
1	1·4	1·6	1·8	1·10	1·1	1·3
2	2·8	3·	3·4	3·8	2·1	2·6
3	4·	4·6	5·	5·6	3·2	3·9
4	5·4	6·	6·8	7·4	4·2	5·
5	6·8	7·6	8·4	9·2	5·3	6·3
6	8·	9·	10·	11·	6·3	7·6
7	9·4	10·6	11·8	12·10	7·4	8·9
8	10·8	12·	13·4	14·8	8·4	10·
9	12·	13·6	5·	16·6	9·5	11·3
10	13·4	15·	16·8	18·4	10·5	12·6
11	14·8	16·6	18·4	20·2	11·6	13·9
12	16·	18·	20·	22·	12·6	15·
13	17·4	19·6	21·8	23·10	13·7	16·3
14	18·8	21·	23·4	25·8	14·7	17·6
15	20·	22·6	25·	27·6	15·8	18·9
16	21·4	24·	26·8	29·4	16·8	20·
17	22·8	25·6	28·4	31·2	17·9	21·3
18	24·	27	30·	33·	18·9	22·6
19	25·4	28·6	31·8	34·10	19·10	23·9
20	26·8	30	33·4	36·8	20·10	25·
21	28·	31·6	35·	38·6	21·11	26·3
22	29·4	33·	36·8	40·4	22·11	27·6
23	30·8	34·6	38·4	42·2	24·	28·9
24	32·	36·	40·	44·	25·	30·

Length.	2½ by 7.	2½ by 8.	2½ by 9.	2½ by 10.	2½ by 11.	2½ by 12.
1	1·6	1·8	1·11	2·1	2·4	2·6
2	2·11	3·4	3·9	4·2	4·7	5.
3	4·5	5·	5·8	6·3	7·	7·6
4	5·10	6·8	7.6	8·4	9·2	10·
5	7·4	8·4	9·5	10·5	11·6	12·6
6	8·9	10·	11·3	12·6	13·9	15·
7	10·3	11·8	13·2	14·7	16·	17·6
8	11·8	13·4	15·	16·8	18·4	20·
9	13·2	15·	16·11	18·9	20·8	22·6
10	14·7	16·8	18·9	20·10	23·	25·
11	16·1	18·4	20·8	22·11	25·3	27·6
12	17·6	20·	22·6	25·	27·6	30·
13	19·	21·8	24·5	27·1	29·10	32·6
14	20·5	23·4	26·3	29·2	32·1	35·
15	21·11	25·	28·2	31·3	34·4	37·6
16	23·4	26·8	30·	33·4	36·8	40·
17	24·10	28·4	31·11	35·5	39·	42·6
18	26·3	30·	33·9	37.6	41·3	45·
19	27·9	31·8	35·8	39·7	43·7	47·6
20	29·2	33·4	37·6	41·8	45·10	50·
21	30·8	35·	39·5	43·9	48·2	52·6
22	32·1	36·8	41·3	45·10	50·5	55·
23	33·7	38·4	43·2	47·11	52·9	57·6
24	35·	40·	45·	50·	55·	60·

3 by 3.		3 by 4.		3 by 5.		3 by 6.		3 by 7.		3 by 8.	
Length 1	0·9	Length 1	1·	Length 1	1·3	Length 1	1·6	Length 1	1·9	Length 1	2·
2	1·6	2	2·	2	2·6	2	3·	2	3·6	2	4·
3	2·3	3	3·	3	3·9	3	4·6	3	5·3	3	6·
4	3·	4	4·	4	5·	4	6·	4	7·	4	8·
5	3·9	5	5·	5	6·3	5	7·6	5	8·9	5	10·
6	4·6	6	6·	6	7·6	6	9·	6	10·6	6	12·
7	5·3	7	7·	7	8·9	7	10·6	7	12·3	7	14·
8	6·	8	8·	8	10·	8	12·	8	14·	8	16·
9	6·9	9	9·	9	11·3	9	13·6	9	15·9	9	18
10	7·6	10	10·	10	12·6	10	15·	10	17·6	10	20·
11	8·3	11	11·	11	13·9	11	16·6	11	19·3	11	22·
12	9·	12	12·	12	15·	12	18·	12	21·	12	24·
13	9·9	13	13·	13	16·3	13	19·6	13	22·9	13	26·
14	10·6	14	14·	14	17·6	14	21·	14	24·6	14	28·
15	11·3	15	15·	15	18·9	15	22·6	15	26·3	15	30·
16	12·	16	16·	16	20·	16	24·	16	28·	16	32·
17	12·9	17	17·	17	21·3	17	25·6	17	29·9	17	34·
18	13·6	18	18·	18	22·6	18	27·	18	31·6	18	36·
19	14·3	19	19·	19	23·9	19	28·6	19	33·3	19	38·
20	15·	20	20·	20	25·	20	30·	20	35·	20	40·
21	15·9	21	21·	21	26·3	21	31·6	21	36·9	21	42·
22	16·6	22	22·	22	27·6	22	33·	22	38·6	22	44·
23	17·3	23	23·	23	28·9	23	34·6	23	40·3	23	46·
24	18·	24	24·	24	30·	24	36·	24	42.	24	48·

3 by 9.		3 by 10.		3 by 11.		3 by 12.		4 by 4.		4 by 5.	
Length 1	2·3	Length 1	2·6	Length 1	2·9	Length 1	3·	Length 1	1·4	Length 1	1·8
2	4·6	2	5·	2	5·6	2	6·	2	2·8	2	3·4
3	6·9	3	7·6	3	8·3	3	9·	3	4·	3	5·
4	9·	4	10·	4	11·	4	12·	4	5·4	4	6·8
5	11·3	5	12·6	5	13·9	5	15·	5	6·8	5	8·4
6	13·6	6	15·	6	16·6	6	18·	6	8·	6	10·
7	15·9	7	17·6	7	19·3	7	21·	7	9·4	7	11·8
8	18·	8	20·	8	22·	8	24·	8	10·8	8	13·4
9	20·3	9	22·6	9	24·9	9	27·	9	12·	9	15·
10	22·6	10	25·	10	27·6	10	30·	10	13·4	10	16·8
11	24·9	11	27·6	11	30·3	11	33·	11	14·8	11	18·4
12	27·	12	30·	12	33·	12	36·	12	16·	12	20·
13	29·3	13	32·6	13	35·9	13	39·	13	17·4	13	21·8
14	31·6	14	35·	14	38·6	14	42·	14	18·8	14	23·4
15	33 9	15	37·6	15	41·3	15	45·	15	20·	15	25·
16	36·	16	40·	16	44·	16	48·	16	21·4	16	26·8
17	38·3	17	42·6	17	46·9	17	51·	17	22·8	17	28·4
18	40·6	18	45·	18	49·6	18	54·	18	24·	18	30·
19	42·9	19	47·6	19	52·3	19	57·	19	25·4	19	31·8
20	45·	20	50·	20	55·	20	60·	20	26·8	20	33·4
21	47·3	21	52·6	21	57·9	21	63·	21	28·	21	35·
22	49·6	22	55·	22	60·6	22	66·	22	29·4	22	36·8
53	51·9	23	57·6	23	63·3	23	69·	23	30·8	23	38·4
24	54·	24	60·	24	66·	24	72·	24	32·	24	40·

4 by 6.		4 by 7.		4 by 8.		4 by 9.		4 by 10.		4 by 11.	
Length.		Length.		Length.		Length.		Length.		Length.	
1	2·	1	2·4	1	2·8	1	3·	1	3·4	1	3·8
2	4·	2	4·8	2	5·4	2	6·	2	6·8	2	7·4
3	6·	3	7·	3	8·	3	9·	3	10·	3	11·
4	8·	4	9·4	4	10·8	4	12·	4	13·4	4	14·8
5	10·	5	11·8	5	13·4	5	15·	5	16·8	5	18·4
6	12·	6	14·	6	16·	6	18·	6	20·	6	22·
7	14·	7	16·4	7	18·8	7	21·	7	23·4	7	25·8
8	16·	8	18·8	8	21·4	8	24·	8	26·8	8	29·4
9	18·	9	21·	9	24·	9	27·	9	30·	9	33
10	20·	10	23·4	10	26·8	10	30·	10	33·4	10	36·8
11	22·	11	25·8	11	29·4	11	33·	11	36·8	11	40·4
12	24·	12	28·	12	32·	12	36·	12	40·	12	44·
13	26·	13	30·4	13	34·8	13	39·	13	43·4	13	47·8
14	28·	14	32·8	14	37·4	14	42·	14	46·8	14	51·4
15	30·	15	35·	15	40·	15	45·	15	50·	15	55·
16	32·	16	37·4	16	42·8	16	48·	16	53·4	16	58·8
17	34·	17	39·8	17	45·4	17	51·	17	56·8	17	62·4
18	36·	18	42·	18	48·	18	54·	18	60·	18	66·
19	38·	19	44·4	19	50·8	19	57·	19	63·4	19	69·8
20	40·	20	46·8	20	53·4	20	60·	20	66·8	20	73·4
21	42·	21	49·	21	56·	21	63·	21	70·	21	77·
22	44·	22	51·4	22	58·8	22	66·	22	73·4	22	80·8
23	46·	23	53·8	23	61·4	23	69·	23	76·8	23	84·4
24	48·	24	56·	24	64·	24	72·	24	80·	24	88·

4 by 12.		5 by 5.		5 by 6.		5 by 7.		5 by 8.		5 by 9.	
Length.		Length.		Length.		Length.		Length.		Length.	
1	4·	1	2·1	1	2·6	1	2·11	1	3·4	1	3·9
2	8·	2	4·2	2	5·	2	5·10	2	6·8	2	7·6
3	12·	3	6·3	3	7·6	3	8·9	3	10·	3	11·3
4	16·	4	8·4	4	10·	4	11·8	4	13·4	4	15·
5	20·	5	10·5	5	12·6	5	14·7	5	16·8	5	18·9
6	24·	6	12·6	6	15·	6	17·6	6	20·	6	22·6
7	28·	7	14·7	7	17·6	7	20·5	7	23·4	7	26·3
8	32·	8	16·8	8	20·	8	23·4	8	26·8	8	30·
9	36·	9	18·9	9	22·6	9	26·3	9	30·	9	33·9
10	40·	10	20·10	10	25·	10	29·2	10	33·4	10	37·6
11	44·	11	22·11	11	27·6	11	32·1	11	36·8	11	41·3
12	48·	12	25·	12	30·	12	35·	12	40·	12	45·
13	52·	13	27·1	13	32·6	13	37·11	13	43·4	13	48·9
14	56·	14	29·2	14	35·	14	40·10	14	46·8	14	52·6
15	60·	15	31·3	15	37·6	15	43·9	15	50·	15	56·3
16	64·	16	33·4	16	40·	16	46·8	16	53·4	16	60·
17	68·	17	35·5	17	42·6	17	49·7	17	56·8	17	63.9
18	72·	18	37·6	18	45·	18	52·6	18	60·	18	67·6
19	76·	19	39·7	19	47·6	19	55·5	19	63·4	19	71·3
20	80·	20	41·8	20	50·	20	58·4	20	66·8	20	75·
21	84·	21	43·9	21	52·6	21	61·3	21	70·	21	78·9
22	88·	22	45·10	22	55·	22	64·2	22	63·4	22	82·6
23	92·	23	47·11	23	57·6	23	67·1	23	76·8	23	86·3
24	96·	24	50·	24	60.	24	70·	24	80·	24	90·

5 by 10.		6 by 6.		6 by 7.		6 by 8.		7 by 7.		7 by 8.	
Length.		Length.		Length.		Length.		Length.		Length.	
1	4·2	1	3·	1	3·6	1	4·	1	4·1	1	4·8
2	8·4	2	6·	2	7·	2	8·	2	8·2	2	9·4
3	12·6	3	9·	3	10·6	3	12·	3	12·3	3	14·
4	16·8	4	12·	4	14·	4	16·	4	16·4	4	18·8
5	20·10	5	15·	5	17·6	5	20·	5	20·5	5	24·4
6	25·	6	18·	6	21·	6	24·	6	24·6	6	28·
7	29·2	7	21·	7	24·6	7	28·	7	28·7	7	32·8
8	33·4	8	24·	8	28·	8	32·	8	32·8	8	37·4
9	37·6	9	27·	9	31·6	9	36·	9	36·9	9	42·
10	41·8	10	30·	10	35·	10	40·	10	40·10	10	46·8
11	45·10	11	33·	11	38·6	11	44·	11	44·11	11	51·4
12	50·	12	36·	12	42·	12	48·	12	49·	12	56·
13	54·2	13	39·	13	45·6	13	52·	13	53·1	13	60·8
14	58·4	14	42·	14	49·	14	56·	14	57·2	14	65·4
15	62·6	15	45·	15	52·6	15	60·	15	61·3	15	70·
16	66·8	16	48·	16	56·	16	64·	16	65·4	16	74·8
17	70·10	17	51·	17	59·6	17	68·	17	69·5	17	79·4
18	75·	18	54·	18	63·	18	72·	18	73·6	18	84·
19	79·2	19	57·	19	66·6	19	76·	19	77·7	19	88·8
20	83·4	20	60·	20	70·	20	80·	20	81·8	20	93·4
21	87·6	21	63·	21	73·6	21	84·	21	85·9	21	98·
22	91·8	22	66·	22	77·	22	88·	22	89·10	22	102·8
23	95·10	23	69·	23	80·6	23	92·	23	93·11	23	107·4
24	100·	24	72·	24	84·	24	96·	24	98·	24	112·

7 by 9.		8 by 8.		8 by 9.		8 by 10.		9 by 9.		9 by 10.	
Length.		Length.		Length.		Length.		Length.		Length.	
1	5·3	1	5·4	1	6·	1	6·8	1	6·9	1	7·6
2	10·6	2	10·8	2	12·	2	13·4	2	13·6	2	15·
3	15·9	3	16·	3	18·	3	20·	3	20·3	3	22.6
4	21·	4	21·4	4	24·	4	26·8	4	27·	4	30
5	26·3	5	26·8	5	30·	5	33·4	5	33·9	5	37·6
6	31·6	6	32·	6	36·	6	40·	6	40·6	6	45·
7	36·9	7	37·4	7	42·	7	46·8	7	47·3	7	52·6
8	42·	8	42·8	8	48·	8	53·4	8	54·	8	60·
9	47·3	9	48·	9	54·	9	60·	9	60 9	9	67·6
10	52·6	10	53·4	10	60·	10	66·8	10	67 6	10	75·
11	57·9	11	58·8	11	66·	11	73·4	11	74 3	11	82·6
12	63·	12	64·	12	72·	12	80·	12	81·	12	90·
13	68·3	13	69·4	13	78·	13	86·8	13	87·9	13	97·6
14	73·6	14	74·8	14	84·	14	93·4	14	94 6	14	105
15	78·9	15	80·	15	90·	15	100·	15	101 3	15	112·6
16	84·	16	85·4	16	96·	16	106·8	16	108	16	120·
17	89·3	17	90·8	17	102·	17	113·4	17	114 9	17	127·6
18	94·6	18	96·	18	108·	18	120·	18	121 6	18	135
19	99·9	19	101·4	19	114·	19	126·8	19	128·3	19	142·6
20	105·	20	106·8	20	120·	20	133·4	20	135·	20	150·
21	110·3	21	112·	21	126·	21	140·	21	141·9	21	157·6
22	115·6	22	117·4	22	132·	22	146·8	22	148·6	22	165
23	120·9	23	122·8	23	138·	23	153·4	23	155·3	23	172·6
24	126·	24	128·	24	144·	24	160·	24	162·	24	180·

TO FIND THE CHORDIAL PITCH OF ANY GIVEN WHEEL.

We take the number of degrees in a circle, 360, and divide that number by the number of teeth in the wheel, which gives us the number of degrees and minutes to the arc pitch; of this amount, whatever it may be, we take one half and look in a table of natural sines for the sine of the half arc pitch. Then multiply the sine so found by 2 and by the radius in inches, and the product is the chordial pitch.

Example:—What will be the chordial pitch of a pinion 8 inches in diameter and to contain 12 teeth?

> 360° ÷ 12 (No. of teeth) = 30°; take half = 15; now the sine of 15 in the table is ·2588 × 2 = .5176 × 6 (radius of pinion) = 2.0706: which is the true chordial pitch.

Deg	Sine.	Deg.	Sine.	Deg.	Sine.	Deg.	Sine.
0	·00	12	·20791	24	·40673	35	·57357
1	·01745	13	·22495	25	·42261	36	·58778
2	·03489	14	·24192	26	·43837	37	·60181
3	·05233	15	·25881	27	·45399	38	·61566
4	·06975	16	·27563	28	·46947	39	·62932
5	·08715	17	·29237	29	48480	40	·64278
6	·10452	18	·39901	30	·50000	41	·65605
7	·12186	19	·32556	31	·51503	42	·66913
8	·13917	20	·34202	32	·52991	43	·68199
9	·15643	21	·35836	33	·54463	44	·69465
10	·17364	22	37460	34	·55919	45	·70710
11	.19080	23	·39073	..	.....	..	.....

TABLE

OF THE PROPORTIONAL RADII OF WHEELS.

From ¼ to 1 Inch.

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
10	0·405	0·607	0·809	1·011	1·214	1·416	1·618
11	0·444	0·666	0·887	1·109	1·331	1.553	1·775
12	0·483	0·724	0·966	1·207	1·449	1·690	1·932
13	0·522	0·783	1·045	1·306	1·567	1·828	2·089
14	0·562	0·843	1·123	1·404	1·685	1·966	2·247
15	0·601	0·902	1·202	1·503	1·804	2·104	2·405
16	0·641	0·961	1·281	1·602	1·922	2·243	2·563
17	0·680	1·020	1·361	1·701	2·041	2·381	2·721
18	0·720	1·080	1·440	1·800	2·160	2·519	2·879
19	0·759	1·139	1·519	1·899	2·278	2·658	3·038
20	0·799	1·199	1·598	1·998	2·397	2·797	3·196
21	0·839	1·258	1·677	2·097	2·516	2·935	3·355
22	0·878	1·318	1·757	2·196	2·635	3·074	3·513
23	0·918	1·377	1·836	2·295	2·754	3·213	3·672
24	0·958	1·437	1·915	2·394	2·873	3·352	3·831
25	0·997	1·496	1·995	2·493	2·992	3·491	3·989
26	1·037	1·556	2·074	2·593	3·111	3·630	4·148
27	1·077	1·615	2·154	2·692	3·230	3·769	4·307
28	1·116	1·675	2·233	2·791	3·349	3·908	4·466
29	1·156	1·734	2·312	2·890	3·468	4·047	4·625
30	1·196	1·794	2·392	2·990	3·588	4·186	4·783
31	1·236	1·853	2·471	3·089	3·707	4·325	4·942
32	1·275	1·913	2·551	3·188	3·826	4·464	5·101
33	1·315	1·973	2·630	3·288	3·945	4·603	5·260
34	1·355	2·032	2·710	3·387	4·064	4·742	5·419
35	1·394	2·092	2·789	3·486	4·183	4·881	5·578
36	1·434	2·151	2·868	3·586	4·303	5·020	5·737
37	1·474	2·211	3·948	3·685	4·422	5·159	5·896
38	1·514	2·271	3·027	3·784	4·541	5·298	6·055
39	1·553	2·330	3·107	3·884	4·660	5·437	6·214
40	1·593	2·390	3·186	3·983	4·780	5·576	6·373
41	1·633	2·449	3·266	4·082	4·899	5·715	6·532
42	1·673	2·509	3·345	4·182	5·018	5·854	6·691
43	1·712	2·569	3·425	4·281	5·137	5·994	6·850
44	1·752	2·628	3·504	4·381	5·257	6·133	7·009
45	1·792	2·688	3·584	4·480	5·376	6·272	7·168

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
46	1·832	2·748	3·663	4·579	5·495	6·411	7·327
47	1·871	2·807	3·743	4·679	5·614	6·550	7·486
48	1·911	2·867	3·822	4·778	5·734	6·689	7·645
49	1·951	2·927	3·902	4·877	5·853	6·828	7·804
50	1·991	2·986	3·982	4·977	5·972	6·968	7·963
51	2·031	3·046	4·061	5·076	6·092	7·107	8·122
52	2·070	3·105	4·141	5·176	6·211	7·246	8·281
53	2·110	3·165	4·220	5·275	6·330	7·385	8·440
54	2·150	3·225	4·300	5·375	6·449	7·524	8·599
55	2·190	3·284	4·379	5·474	6·569	7·663	8·758
56	2·229	3·344	4·459	5·573	6·688	7·803	8·917
57	2·269	3·404	4·538	5·673	6·807	7·942	9·076
58	2·309	3·463	4·618	5·772	6·927	8·081	9·235
59	2·349	3·523	4·697	5·872	7·046	8·220	9·395
60	2·388	3·583	4·777	5·971	7·165	8·359	9·554
61	2·428	3·642	4·856	6·070	7·285	8·499	9·713
62	2·468	3·702	4·936	6·170	7·404	8·638	9·872
63	2·508	3·762	5·015	6·269	7·523	8·777	10·031
64	2·548	3·821	5·095	6·369	7·643	8·916	10·190
65	2·587	3·881	5·175	6·468	7·762	9·055	10·349
66	2·627	3·941	5·254	6·568	7·881	9·195	10·508
67	2·667	4·000	5·334	6·667	8·000	9·334	10·667
68	2·707	4·060	5·413	6·767	8·120	9·473	10·826
69	2·746	4·120	5·493	6·866	8·239	9·612	10·985
70	2·786	4·179	5·572	6·965	8·358	9·752	11·145
71	2·826	4·239	5·652	7·065	8·478	9·891	11·304
72	2·836	4·299	5·731	7·164	8·597	10·030	11·463
73	2·905	4·358	5·811	7·264	8·716	10·169	11·622
74	2·945	4·418	5·890	7·363	8·836	10·308	11·781
75	2·985	4·478	5·970	7·463	8·955	10·448	11·940
76	3·025	4·537	6·050	7·562	9·074	10·587	12·099
77	3·065	4·597	6·129	7·631	9·194	10·726	12·258
78	3·104	4·657	6·209	7·761	9·313	10·865	12·417
79	3·144	4·716	6·288	7·830	9·432	11·004	12·577
80	3·184	4·776	6·368	7·930	9·552	11·144	12·736
81	3·224	4·836	6·447	8·059	9·671	11·283	12·895
82	3·263	4·895	6·527	8·159	9·790	11·422	13·054
83	3·303	4·955	6·607	8·258	9·910	11·561	13·213
84	3·343	5·015	6·686	8·358	10·029	11·701	13·372
85	3·383	5·074	6·766	8·457	10·148	11·840	13·531
86	3·423	5·134	6·845	8·556	10·268	11·979	13·690
87	3·462	5·194	6·925	8·656	10·387	12·118	13·849
88	3·502	5·253	7·004	8·755	10·506	12·258	14·009
89	3·542	5·313	7·084	8·855	10·626	12·397	14·168
90	3·582	5·373	7·163	8·954	10·745	12·536	14·327
91	3·622	5·432	7·243	9·054	10·864	12·675	14·486
92	3·631	5·492	7·323	9·153	10·984	12·815	14·645
93	3·701	5·552	7·402	9·253	11·103	12·954	14·804

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
94	3·741	5·611	7·482	9·352	11·223	13.093	14·963
95	3·781	5·671	7·561	9·452	11·342	13·232	15·122
96	3·820	5·731	7·641	9·551	11·461	13·371	15·282
97	3·860	5·790	7·720	9·650	11·581	13·511	15·441
98	3·900	5·850	7·800	9·750	11·700	13·650	15·600
99	3·940	5·910	7·880	9·849	11·819	13·789	15·759
100	3·980	5·969	7·959	9·949	11·938	13·928	15·918
101	4·019	6·029	8·039	10·048	12·058	14·068	16·077
102	4·059	6·089	8·118	10·148	12·177	14·207	16·236
103	4·099	6·148	8·198	10·247	12·297	14·346	16·396
104	4·139	6·208	8·277	10·347	12·416	14·485	16·555
105	4·178	6·268	8·357	10·446	12·535	14·625	16·714
106	4·218	6·327	8·436	10·546	12·655	14·764	16·873
107	4·258	6·387	8·516	10·645	12·774	14·903	17·032
108	4·298	6·447	8·596	10·744	12·893	15·042	17·191
109	4·338	6·506	8·675	10·844	13·013	15·182	17·350
110	4·377	6·566	8·755	10·943	13·132	15·321	17·509
111	4.417	6·626	8·834	11.043	13·251	15·460	17·669
112	4·457	6·685	8·914	11·142	13·371	15·599	17·828
113	4·497	6·745	8·993	11·242	13·490	15·738	17·987
114	4·536	6·805	9·073	11·341	13·609	15·878	18·146
115	4·576	6·864	9·153	11·441	13·729	16·017	18·305
116	4·616	6·924	9·232	11·540	13·848	16·156	18·464
117	4·656	6·984	9·312	11·640	13·968	16·295	18·623
118	4·696	7·043	9·391	11·739	14·087	16.435	18·782
119	4·735	7·103	9·471	11·839	14·206	16·574	18·942
120	4·775	7·163	9·550	11·938	14·326	16·713	19·101
121	4·815	7·222	9·630	12·037	14·445	16·852	19·260
122	4·855	7·282	9·710	12·137	14·564	16·992	19·419
123	4·895	7·342	9·789	12·236	14·684	17·131	19·578
124	4·934	7·402	9·869	12·336	14·803	17·270	19·737
125	4·974	7·461	9·948	12·435	14·922	17·410	19·896
126	5·014	7·521	10·028	12·535	15·042	17·549	20·056
127	5·054	7·581	10·107	12·634	15·161	17·688	20·215
128	5·093	7·640	10·187	12·734	15·280	17·827	20·374
129	5·133	7·700	10·267	12·833	15·400	17·966	20·533
130	5·173	7·760	10·346	12·933	15·519	18·106	20·692
131	5·213	7·819	10·426	13·032	15·638	18·245	20·851
132	5·253	7.879	10 505	13·132	15·758	18·384	21·010
133	5·292	7·939	10·585	13·231	15·877	18·523	21·170
134	5·332	7·998	10·664	13·331	15·997	18·663	21·329
135	5·372	8·058	10·744	13·430	16·116	18·802	21·488
136	5·412	8·118	10·824	13·529	16·235	18·941	21·647
137	5·452	8·177	10·903	13·629	16·355	19·080	21·806
138	5·491	8·237	10·983	13·728	16·474	19·220	21·965
139	5·531	8·297	11·062	13·828	16·593	19·359	22·124
140	5·571	8·356	11·142	13·927	16·713	19·498	22·284
141	5·611	8·416	11·221	14·027	16·832	19·637	22·443

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
142	5·650	8·476	11·301	14·126	16·951	19·777	22·602
143	5·690	8·535	11·381	14·226	17·071	19·916	22·761
144	5·730	8·595	11·460	14·325	17·190	20·055	22·920
145	5·770	8·655	11·540	14·425	17·309	20·194	23·079
146	5·810	8·714	11·619	14·524	17·429	20·334	23·238
147	5·849	8·774	11·699	14·623	17·548	20·473	23·398
148	5·889	8·834	11·778	14·723	17·668	20·612	23·557
149	5·929	8·893	11·858	14·822	17·787	20·751	23·716
150	5·969	8·953	11·938	14·922	17·906	20·891	23·875
151	6·009	9·013	12·017	15·021	18·026	21·030	24·034
152	6·048	9·072	12·097	15·121	18·145	21·169	24·193
153	6·088	9·132	12·176	15·220	18·264	21·308	24·352
154	6·128	9·192	12·256	15·320	13·384	21·448	24·512
155	6·168	9·252	12·335	15·419	18·503	21·587	24·671
156	6·207	9·311	12·415	15·519	18·622	21·726	24·830
157	6·247	9·371	12·494	15·618	18·742	21·865	24·989
158	6·287	9·431	12·574	15·718	18·861	22·005	25·148
159	6·327	9·490	12·654	15·817	18·980	22·144	25·307
160	6·367	9·550	12·733	15·917	19·100	22·283	25·466
161	6·406	9·610	12·813	16·016	19·219	22·422	25·626
162	6·446	9·669	12·892	16·115	19·339	22·562	25·785
163	6·486	9·729	12·972	16·215	19·458	22·701	25·944
164	6·526	9·789	13·052	16·314	19·577	22·840	26·103
165	6·566	9·848	13·131	16·414	19·697	22·979	26·262
166	6·605	9·908	13·211	16·513	19·816	23·119	26·421
167	6·645	9·968	13·290	16·613	19·935	23·258	26·580
168	6·685	10.027	13·370	16·712	20·055	23·397	26·740
169	6·725	10·087	13·449	16·812	20·174	23·536	26·899
170	6·764	10·147	13·529	16·911	20·293	23·676	27·058
171	6·804	10·206	13·609	17·011	20·413	23·815	27·217
172	6·844	10·266	13·688	17·110	20·532	23·954	27·376
173	6·884	10·326	13·768	17·210	20·651	24·093	27·535
174	6·924	10·385	13·847	17·309	20·771	24·233	27·694
175	6·963	10·445	13·927	17·409	20·890	24·372	27·854
176	7·003	10·505	14·006	17·508	21·010	24·511	28·017
177	7·043	10·564	14·086	17·607	21·129	24·650	28·172
178	7·083	10·624	14·166	17·707	21·248	24·790	28·331
179	7·123	10·684	14·245	17·806	21·368	24·929	28·490
180	7·162	10·744	14·325	17·906	21·487	25·068	28·649
181	7·202	10·803	14·404	18·005	21·606	25·207	28·808
182	7·242	10·863	14·484	18·105	21·726	25·347	28·968
183	7·282	10·923	14·563	18·204	21·845	25·486	29·127
184	7·321	10·982	14·643	18·304	21·964	25·625	29·286
185	7·361	11·042	14·723	18·403	22·084	25·764	29·445
186	7·401	11·102	14·802	18·503	22·203	25·904	29·607
187	7·441	11·161	14·882	18·602	22·323	26·043	29·763
188	7·481	11·221	14·961	18·702	22·442	26·182	29·923
189	7·520	11·281	15·041	18·801	22·561	26·321	30·082

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
190	7·560	11·340	15·120	18·901	22·681	26·461	30·241
191	7·600	11·400	15·200	19·000	22·800	26·600	30·400
192	7·640	11·460	15·280	19·099	22·919	26·739	30·559
193	7·679	11·519	15·359	19·199	23.039	26·878	30·718
194	7·719	11·579	15·439	19·298	23·158	27·018	30·877
195	7·759	11·639	15·518	19·398	23·277	27·157	31·037
196	7·799	11·698	15·598	19·497	23·397	27·296	31·196
197	7·839	11·758	15·677	19·597	23·516	27·436	31·355
198	7·879	11·818	15·757	19·696	23·636	27·575	31·514
199	7·918	11·877	15·837	19·796	23·755	27·714	31·673
200	7·958	11·937	15·916	19·895	23·874	27·853	31·832
201	7·998	11·997	15·996	19·995	23·994	27·993	31·991
202	8·038	12·056	16·075	20·094	24·113	28·132	32·151
203	8·077	12·116	16·155	20·194	24·232	28·271	32·310
204	8·117	12·176	16·234	20·293	24·352	28·410	32·469
205	8·157	12·236	16·314	20·393	24·471	28·550	32·628
206	8·197	12·295	16·394	20·492	24·590	28·689	32·787
207	8·237	12·355	16·473	20·591	24·710	28·828	32·946
208	8·276	12·415	16·553	20·691	24·829	28·967	33·106
209	8·316	12·474	16·632	20·790	24·948	29·107	33·265
210	8·356	12·534	16·712	20·890	25·068	29·246	33·424
211	8·396	12·594	16·791	20·989	25·187	29·385	33·583
212	8·436	12·653	16·871	21·089	25·307	29·524	33·742
213	8·475	12·713	16·951	21·188	25·426	29·664	33·901
214	8·515	12·773	17·030	21·288	25·545	29·803	34·060
215	8·555	12·832	17·110	21·387	25·665	29·942	34·220
216	8·595	12·892	17·189	21·487	25·784	30·081	34·379
217	8·634	12·952	17·269	21·586	25·903	30·221	34·538
218	8·674	13·011	17·349	21·686	26·023	30·360	34·697
219	8·714	13·071	17·420	21·786	26·142	30·499	34·856
220	8·754	13·131	17·508	21·885	26·261	30·638	35·015
221	8·794	13·190	17·587	21·984	26·381	30·778	35·174
222	8·833	13·250	17·667	22·084	26·500	30·917	35·334
223	8·873	13·310	17·746	22·183	26·620	31·056	35·493
224	8·913	13·369	17·826	22·282	26·739	31·195	35·652
225	8·953	13·429	17·906	22·382	26·858	31·335	35·811
226	8·993	13·489	17·985	22·481	26·978	31·474	35·970
227	9·032	13·548	18·065	22·581	27·097	31·613	36·129
228	9·072	13·608	18·144	22·680	27·216	31·752	36·289
229	9·112	13·668	18·224	22·780	27·336	31·892	36·448
230	9·152	13·728	18·303	22·879	27·455	32·031	36·607
231	9·191	13·787	18·383	22·979	27·574	32·170	36.766
232	9·231	13·847	18·463	23·078	27·694	32·309	36·925
233	9·271	13·907	18·542	23·178	27·813	32·449	37·084
234	9·311	13.966	18·622	23·277	27·933	32·588	37·243
235	9·351	14·026	18·701	23·377	28·052	32·727	37·403
236	9·390	14·086	18·781	23·476	28·171	32·867	37·562
237	9·430	14·145	18·860	23·576	28·291	33·006	37·721

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
238	9·470	14·205	18·940	23·675	28·410	33·145	37·880
239	9·510	14·265	19·020	23·774	28·529	33·284	38·039
240	9·550	14·324	19·099	23·874	28·649	33·424	38·198
241	9·589	14·384	19·179	23·973	28·768	33·563	38·357
242	9·629	14·444	19·258	24·073	28·887	33·702	38·517
243	9·669	14·503	19·338	24·172	29·007	33·841	38·676
244	9·709	14·563	19·417	24·272	29·126	33·981	38·835
245	9·749	14·623	19·497	24·371	29·246	34·120	38·994
246	9·788	14·682	19·577	24·471	29·365	34·259	39·153
247	9·828	14·742	19·656	24·570	29·484	34·398	39·312
248	9.868	14·802	19·736	24·670	29·604	34·538	39·472
249	9·908	14·861	19·815	24·769	29·723	34·677	39·631
250	9·947	14·921	19·895	24·869	29·842	34·816	39·790
251	9·987	14·981	19·974	24·968	29·962	34·955	39·949
252	10·027	15·041	20·054	25·068	30·081	35·095	40·108
253	10·067	15·100	20·134	25·167	30·200	35·234	40·267
254	10·107	15·160	20·213	25·267	30·320	35·373	40·426
255	10·146	15·220	20·293	25·366	30·439	35·512	40·586
256	10·186	15·279	20·372	25·465	30·559	35·652	40·745
257	10·226	15·339	20·452	25·565	30·678	35·791	40·904
258	10·266	15·399	20·532	25·664	30·797	35·930	41·063
259	10·306	15·458	20·611	25·764	30·917	36·069	41·222
260	10·345	15·518	20·691	25·863	31·036	36·209	41·381
261	10·385	15·578	20·770	25·963	31·155	36·348	41·540
262	10·425	15·637	20·850	26·062	31·275	36·487	41·700
263	10·465	15·697	20·929	26·162	31·394	36·626	41·859
264	10·504	15·757	21·009	26·261	31·513	36·766	42·018
265	10·544	15·816	21·089	26.361	31·633	36·905	42·177
266	10·584	15·876	21·168	26·460	31·752	37·044	42·336
267	10·624	15·936	21·248	26·560	31·872	37·183	42·495
268	10·664	15·995	21·327	26·659	31·991	37·323	42·655
269	10·703	16·055	21·407	26·759	32·110	37·462	42·814
270	10·743	16·115	21·486	26·858	32·230	37·601	42·973
271	10·783	16·175	21·566	26·958	32·349	37·741	43·132
272	10·823	16·234	21·646	27·057	32·468	37·880	43·291
273	10·863	16·294	21·725	27·156	32·588	38·019	43·450
274	10·902	16·354	21·805	27·256	32·707	38·158	43·609
275	10·942	16·413	21·884	27·355	32·826	38·298	43·769
276	10·982	16·473	21·964	27·455	32·946	38·437	43·928
277	11·022	16·533	22·043	27·554	33·065	38·576	44·087
278	11·062	16·592	22·123	27·654	33·185	38·715	44·246
279	11·101	16·652	22·203	27·753	33·304	38·855	44·405
280	11·141	16·712	22·282	27·853	33·423	38·994	44·564
281	11·181	16·771	22·362	27·952	33·543	39·133	44·724
282	11·221	16·831	22·441	28·052	33·662	39·272	44·883
283	11·260	16·891	22·521	28·151	33·781	39·412	45·042
284	11·300	16·950	22·600	28·251	33·901	39·551	45·201
285	11·340	17·010	22·680	28·350	34·020	39·690	45·360

No. of teeth.	¼	⅜	½	⅝	¾	⅞	1
286	11.380	17·070	22·760	28·450	34·139	39·829	45·519
287	11·420	17·129	22·839	28·549	34·259	39·969	45·678
288	11·459	17·189	22·919	28·648	34·378	40·108	45·838
289	11·499	17·249	22·998	28·748	34·498	40·247	45·997
290	11·539	17·308	23·078	28·847	34·617	40·386	46·156
291	11·579	17·368	23·158	28·947	34·736	40·526	46·315
292	11·619	17·428	23·237	29·046	34·856	40·665	46·474
293	11·6 8	17·488	23·317	29·146	34·975	40·804	46·633
294	11·698	17·547	23·396	29·245	35·094	40·943	46·792
295	11·738	17·607	23·476	29·345	35·214	41·083	46·952
296	11·778	17·667	23·555	29·444	35·333	41·222	47·111
297	11·817	17·726	23·635	29·544	35·452	41·361	47·270
298	11·857	17·786	23·715	29·643	35·572	41·500	47·429
299	11·897	17·846	23·794	29·743	35·691	41·640	47·588
300	11·937	17·905	23·874	29.842	35·811	41·779	47·747

TABLE

OF THE PROPORTIONAL RADII OF WHEELS.

From 1¼ to 3 Inches Pitch.

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
15	3·006	3·607	4·209	4·810	5·411	6·012	7·215
16	3·204	3·844	4·485	5·126	5·767	6·407	7·689
17	3·401	4 082	4·762	5·442	6·122	6·803	8·163
18	3·599	4·319	5·039	5·759	6·479	7·198	8·638
19	3·797	4·557	5·316	6·076	6·835	7·594	9·113
20	3·995	4·794	5·593	6·392	7·192	7·991	9·589
21	4·193	5·032	5·871	6·710	7·548	8·387	10.064
22	4·392	5·270	6·148	7·027	7·905	8·783	10·540
23	4·590	5·508	6·426	7·344	8·262	9·180	11·016
24	4·788	5·746	6·704	7·661	8·619	9·577	11·492
25	4·987	5·984	6·981	7·979	8·976	9·973	11·968
26	5·185	6·222	7·259	8·296	9·333	10·370	12·444
27	5·384	6·460	7·537	8·614	9·691	10·767	12·921
28	5·582	6·699	7·815	8·931	10·048	11·164	13·397
29	5·781	6·937	8·093	9·249	10·405	11·561	13·874
30	5·979	7·175	8·371	9·567	10·763	11·958	14·350
31	6·178	7·413	8·649	9·885	11·120	12·356	14·827
32	6·376	7·652	8·927	10·202	11·478	12·753	15·303
33	6·575	7·890	9·205	10·520	11·835	13·150	15·780
34	6·774	8·128	9·483	10·838	12·193	13·547	16·257

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
35	6·972	8·367	9·761	11·156	12·550	13·945	16·734
36	7·171	8·605	10·040	11·474	12·908	14·342	17·211
37	7·370	8·844	10·318	11·972	13·266	14·740	17·688
38	7·569	9·082	10·596	12·110	13·623	15·137	18·164
39	7·767	9·321	10·874	12·428	13·981	15·534	18·641
40	7·966	9·559	11·152	12·746	14·339	15·932	19·118
41	8·165	9·798	11·431	13·064	14·696	16·329	19·595
42	8·363	10·036	11·709	13·382	15·054	16·727	20·072
43	8·562	10·275	11·987	13·700	15·412	17·124	20·549
44	8·761	10·513	12·265	14·018	15·770	17·522	21·026
45	8·960	10·752	12 544	14·336	16·128	17·920	21·503
46	9·159	10·990	12·822	14·654	16·485	18·317	21·981
47	9·357	11·229	13·100	14·972	16·843	18·715	22·458
48	9·556	11·467	13·379	15·290	17·201	19·112	22·935
49	9·755	11·706	13·657	15·608	17·559	19·510	23·412
50	9·954	11·945	13·935	15·926	17·917	19·908	23·889
51	10·153	12·183	14·214	16·244	18·275	20·305	24·366
52	10·351	12·422	14·492	16·562	18·633	20·703	24·843
53	10 550	12·660	14·770	16·880	18·990	21·100	25·320
54	10·749	12·899	15·049	17·198	19·348	21·498	25·798
55	10·948	13·137	15·327	17·517	19·706	21·896	26·275
56	11·147	13·376	15·605	17·835	20·064	22·293	26·752
57	11·346	13·615	15·884	18·153	20·422	22·691	27·229
58	11·544	13·853	16·162	18·471	20·780	23·089	27·706
59	11·743	14·092	16·441	18·789	21·138	23·486	28·184
60	11·942	14·330	16·719	19·107	21·496	23·884	28·661
61	12·141	14·569	16·997	19·425	21·854	24·282	29·138
62	12·340	14·808	17·276	19·744	22·212	24·680	29·615
63	12·539	15·046	17·554	20 062	22·570	25·077	30·093
64	12·738	15·285	17·833	20·380	22·928	25·475	30·570
65	12·936	15·524	18·111	20·698	23·285	25·873	31·047
66	13·135	15·762	18·389	21·016	23·643	26·270	31·525
67	13·334	16·001	18·668	21·335	24·001	26·668	32·002
68	13·533	16·240	18·946	21·653	24·359	27·066	32·479
69	13·732	16·478	19·225	21·971	24·717	27·464	32·956
70	13·931	16·717	19·503	22·289	25·075	27·861	33·434
71	14·130	16·956	19·781	22·607	25·433	28·259	33·911
72	14·328	17·194	20·060	22·926	25·791	28·657	34·388
73	14·527	17·433	20·338	23·244	26·149	29·055	34·866
74	14·726	17·671	20·617	23·562	26·507	29·452	35·343
75	14·925	17·910	20·895	23·880	26·865	29·850	35·820
76	15·124	18·149	21·174	24·198	27·223	30·248	36·298
77	15·323	18·387	21·452	24·517	27·581	30·646	36·775
78	15·522	18·626	21·731	24·835	27·939	31·044	37·252
79	15·721	18·865	22·009	25·153	28·297	31·441	37·730
80	15·920	19·103	22·287	25·471	28·655	31·839	38·207
81	16·118	19·342	22·566	25·790	29·013	32·237	38·684
82	16·317	19·581	22·844	26·108	29·371	32.635	39·162

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
83	16·516	19·820	23·123	26·426	29·729	33·033	39·639
84	16·715	20·058	23·401	26·744	30·087	33·430	40·116
85	16·914	20·297	23·680	27·063	30·445	33·828	40·594
86	17·113	20·536	23·958	27·381	30·803	34·226	41·071
87	17·312	20·774	24·237	27·699	31·161	34·624	41·548
88	17·511	21·013	24·515	28·017	31·519	35·022	42·026
89	17·710	21·252	24·794	28·335	31·877	35·419	42·503
90	17·909	21·490	25·072	28·654	32·235	35·817	42·981
91	18·107	21·729	25·350	28·972	32·593	36·215	43·458
92	18·306	21·968	25·629	29·290	32·952	36·613	43·935
93	18·505	22·206	25·907	29·608	33·309	37·011	44·413
94	18·704	22·445	26·186	29·927	33·668	37·408	44·890
95	18·903	22·684	26·464	30·245	34·026	37·806	45·367
96	19·102	22·922	26·743	30·563	34·384	38·204	45·845
97	19·301	23·161	27·021	30·881	34·742	38·602	46·322
98	19·500	23·400	27·300	31·200	35·100	39·000	46·800
99	19·699	23·638	27·578	31·518	35·458	39·397	47·277
100	19·898	23·877	27·857	31·836	35·816	39·795	47·754
101	20·097	24·116	28·135	32·155	36·174	40·193	48·232
102	20·295	24·355	28·414	32·473	36·532	40·591	48·709
103	20·494	24·593	28·692	32·791	36·890	40·989	49·187
104	20·693	24·832	28·971	33·109	37·248	41·387	49·664
105	20·892	25·071	29·249	33·428	37·606	41·784	50·141
106	21·091	25·309	29·528	33·746	37·964	42·182	50·619
107	21·290	25·548	29·806	34·064	38·322	42·580	51·096
108	21·489	25·787	30·084	34·382	38·680	42·978	51·573
109	21·688	26·025	30·363	34·701	39·038	43·376	52·051
110	21·887	26·264	30·641	35·019	39·396	43·774	52·528
111	22·086	26·503	30·920	35·337	39·754	44·171	53·006
112	22·285	26·742	31·198	35·655	40·112	44·569	53·483
113	22·484	26·980	31·477	35·974	40·470	44·967	53·960
114	22·682	27·219	31·755	36·292	40·828	45·365	54·438
115	22·881	27·458	32·034	36·610	41·186	45·763	54·915
116	23·080	27·696	32·312	36·928	41·544	46.161	55·393
117	23·279	27·935	32·591	37·247	41·903	46·558	55·870
118	23·478	28·174	32·869	37·565	42·261	46·956	56·347
119	23·677	28·412	33·148	37·883	42·619	47·354	56·825
120	23·876	28·651	33·426	38·202	42·977	47·752	57·302
121	24·075	28·890	33·705	38·520	43·335	48·150	57·780
122	24·274	29·129	33·983	38·838	43·693	48·548	58·257
123	24·473	29·367	34·262	39·156	44·051	48·945	58·735
124	24.672	29·606	34·540	39·475	44·409	49·343	59·212
125	24.871	29·845	34·819	39·793	44·767	49·741	59·690
126	25·070	30·083	35·097	40·111	45·125	50·139	60·167
127	25·268	30·322	35·376	40·429	45·483	50·537	60·644
128	25·467	30·561	35·654	40·748	45·841	50·935	61·122
129	25·666	30·800	35·933	41·036	46·199	51·333	61·599
130	25·865	31·038	36·211	41·384	46·557	51·730	62·077

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
131	26·064	31·277	36·490	41·703	46·915	52·128	62·554
132	26·263	31·516	36·768	42·021	47·274	52·526	63·031
133	26·462	31·754	37·047	42·339	47·632	52·924	63·509
134	26·661	31·993	37·325	42·657	47·990	53·322	63·986
135	26·860	32·232	37·604	42·976	48·348	53·720	64·464
136	27·059	32·471	37·882	43·294	48·706	54·118	64·941
137	27·258	32·709	38·161	43·612	49·064	54·515	65·418
138	27·457	32·948	38·439	43·931	49·422	54·913	65·896
139	27·656	33·187	38·718	44·249	49·780	55·311	66·373
140	27·855	33·426	38·996	44·567	50·138	55·709	66·851
141	28·053	33·664	39·275	44·885	50·496	56·107	67·328
142	28·252	33·903	39·553	45·204	50·854	56·505	67·806
143	28·451	34·141	39·832	45·522	51·212	56·902	68·283
144	28·650	34·380	40·110	45·840	51·570	57·300	68·760
145	28·849	34·619	40·389	46·159	51·928	57·698	69·238
146	29·048	34·858	40·667	46·477	52·286	58·096	69·715
147	29·247	35·096	40·946	46·795	52·645	58·494	70·193
148	29·446	35·335	41·224	47·113	53·003	58·892	70·670
149	29·645	35·574	41·503	47·432	53·361	59·290	71·148
150	29·844	35·813	41·781	47·750	53·719	59·687	71·625
151	30·043	36·051	42·060	48·068	54·077	60·085	72·102
152	30·242	36·290	42·338	48·387	54·435	60·483	72·580
153	30·441	36·529	42·617	48·705	54·793	60·881	73·057
154	30·639	36·767	42·895	49·023	55·151	61·279	73·535
155	30·838	37·006	43·174	49·341	55·509	61·677	74·012
156	31·037	37·245	43·452	49·660	55·867	62·075	74·490
157	31·236	37·483	43·731	49·978	56·225	62·472	74·967
158	31·435	37·722	44·009	50·296	56·583	62·870	75·444
159	31·634	37·961	44·288	50·615	56·941	63·268	75·922
160	31·833	38·200	44·566	50·933	57·299	63·666	76·399
161	32·032	38·438	44·845	51·251	57·658	64·064	76·877
162	32·231	38·677	45·123	51·569	58·016	64·462	77·354
163	32·430	38·916	45·402	51·888	58·374	64·860	77·832
164	32·629	39·155	45·680	52·206	58·732	65·258	78·309
165	32·828	39·393	45·959	52·524	59·090	65·655	78·786
166	33·027	39·632	46·237	52·843	59·448	66·053	79·264
167	33·226	39·871	46·516	53·161	59·806	66·451	79·741
168	33·425	40·109	46·794	53·479	60·164	66·849	80·219
169	33·623	40·348	47·073	53·797	60·522	67·247	80·696
170	33·822	40·587	47·351	54·116	60·880	67·645	81·174
171	34·021	40·826	47·630	54·434	61·238	68·043	81·651
172	34·220	41·064	47·908	54·752	61·596	68·440	82·129
173	34·419	41·303	48·187	55·071	61·954	68·838	82·606
174	34·618	41·542	48·465	55·389	62·313	69·236	83·083
175	34·817	41·780	48·744	55·707	62·671	69·634	83·561
176	35·016	42·019	49·022	56·026	63·029	70·032	84·038
177	35·215	42·258	49·301	56·344	63·387	70·430	84·516
178	35·414	42·497	49·579	56·662	63·745	70·828	84·993

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
179	35·613	42·735	49·858	56·980	64·103	71·226	85·471
180	35·812	42·974	50·136	57·299	64·461	71·623	85·948
181	36·011	43·213	50·415	57·617	64·819	72·021	86·425
182	36·210	43·451	50·693	57·935	65·177	72·419	86·903
183	36·408	43·690	50·972	58·254	65·535	72·817	87·380
184	36·607	43·929	51·250	58·572	65·893	73·215	87·858
185	36·806	44·168	51·529	58·890	66·251	73·613	88·335
186	37·005	44·406	51·807	59·208	66·610	74·011	88·813
187	37·204	44·645	52·086	59·527	66·968	74·408	89·290
188	37·403	44·884	52·364	59·845	67·326	74·806	89·768
189	37·602	45·123	52·643	60·163	67·684	75·204	90·245
190	37·801	45·361	52·921	60·482	68·042	75·602	90·722
191	38·000	45·600	53·200	60·800	68·400	76·000	91·200
192	38·199	45·839	53·478	61·118	68·758	76·398	91·677
193	38·398	46·077	53·757	61·437	69·116	76·796	92·155
194	38·597	46·316	54·035	61·755	69·474	77·194	92·632
195	38·796	46·555	54·314	62·073	69·832	77·591	93·110
196	38·995	46·794	54·593	62·391	70·190	77·999	93·587
197	39·194	47·032	54·871	62·710	70·548	78·387	94·065
198	39·393	47·271	55·150	63·028	70·907	78·785	94·542
199	39·591	47·510	55·428	63·346	71·265	79·183	95·019
200	39·790	47·748	55·707	63·665	71·623	79·581	95·497
201	39·989	47·987	55·985	63·983	71·981	79·979	95·974
202	40·188	48·226	56·264	64·301	72·339	80·377	96·452
203	40·387	48·465	56·542	64·619	72·697	80·774	96·929
204	40·586	48·703	56·821	64·938	73·055	81·172	97·407
205	40·785	48·942	57·099	65·256	73·413	81·570	97·884
206	40·984	49·181	57·378	65·574	73·771	81·968	98·362
207	41·183	49·420	57·656	65·893	74·129	82·366	98·839
208	41·382	49·658	57·935	66·211	74·487	82·764	99·317
209	41·581	49·897	58·213	66·529	74·845	83·162	99·794
210	41·780	50·136	58·492	66·848	75·204	83·560	100·271
211	41·979	50·374	58·770	67·166	75·562	83·957	100·749
212	42·178	50·613	59·049	67·484	75·920	84·355	101·226
213	42·377	50·852	59·327	67·803	76·278	84·753	101·704
214	42·576	51·091	59·606	68·121	76·636	85·151	102·181
215	42·774	51·329	59·884	68·439	76·994	85·549	102·659
216	42·973	51·568	60·163	68·757	77·352	85·947	103·136
217	43·172	51·807	60·441	69·076	77·710	86·345	103·614
218	43·371	52·046	60·720	69·394	78·068	86·743	104·091
219	43·570	52·284	60·998	69·712	78·426	87·140	104·568
220	43·769	52·523	61·277	70·031	78·784	87·538	105·046
221	43·968	52·762	61·555	70·349	79·143	87·936	105·523
222	44·167	53·000	61·834	70·667	79·501	88·334	106·001
223	44·366	53·239	62·112	70·986	79·859	88·732	106·478
224	44·565	53·478	62·391	71·304	80·217	89·130	106·956
225	44·764	53·717	62·669	71·622	80·575	89·528	107·433
226	44·963	53·955	62·948	71·940	80·933	89·926	107·911

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
227	45·162	54·194	63·226	72·259	81·291	90·323	108·388
228	45·361	54·433	63·505	72·577	81·649	90·721	108·866
229	45·560	54·672	63·783	72·895	82·007	91·119	109·343
230	45·759	54·910	64·062	73·214	82·365	91·517	109·820
231	45·957	55·149	64·340	73·532	82·723	91·915	110·298
232	46·156	55·388	64·619	73·850	83·082	92·313	110·775
233	46·355	55·626	64·897	74·169	83·440	92·711	111·253
234	46·554	55·865	65·176	74·487	83·798	93·109	111·730
235	46·753	56·104	65·454	74·805	84·156	93·506	112·208
236	46·952	56·343	65·733	75·123	84·514	93·904	112·685
237	47·151	56·581	66·012	75·442	84·872	94·302	113·163
238	47·350	56·820	66·290	75·760	85·230	94·700	113·640
239	47·549	57·059	66·569	76·078	85·588	95·098	114·117
240	47·748	57·297	66·847	76·397	85·946	95·496	114·595
241	47·947	57·536	67·126	76·715	86·304	95·894	115·072
242	48·146	57·775	67·404	77·033	86·662	96·292	115·550
243	48·345	58·014	67·683	77·352	87·020	96·689	116·027
244	48·544	58·252	67·961	77·670	87·379	97·087	116·505
245	48·743	58·491	68·240	77·988	87·737	97·485	116·982
246	48·942	58·730	68·518	78·306	88·095	97·883	117·460
247	49·140	58·969	68·797	78·625	88·453	98·281	117·937
248	49·339	59·207	69·075	78·943	88·811	98·679	118·415
249	49·538	59·446	69·354	79·261	89·169	99·077	118·892
250	49·737	59·685	69·632	79·580	89·527	99·475	119·369
251	49·936	59·923	69·911	79·898	89·885	99·872	119·847
252	50·135	60·162	70·189	80·216	90·243	100·270	120·324
253	50·334	60·401	70·468	80·535	90·601	100·668	120·802
254	50·533	60·640	70·746	80·853	90·959	101·066	121·279
255	50·732	60·878	71·025	81·171	91·318	101·464	121·757
256	50·931	61·117	71·303	81·489	91·676	101·862	122·234
257	51·130	61·356	71·582	81·808	92·034	102·260	122·712
258	51·329	61·595	71·860	82·126	92·392	102·658	123·189
259	51·528	61·833	72·139	82·444	92·750	103·055	123·667
260	51·727	62·072	72·417	82·763	93·108	103·453	124·144
261	51·926	62·311	72·696	83·081	93·466	103·851	124·621
262	52·125	62·549	72·974	83·399	93·824	104·249	125·099
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266	52·920	63.504	74·088	84·673	95·257	105·841	127·009
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272	54·114	64·937	75·760	86·582	97·405	108·228	129·873
273	54·313	65·175	76·038	86·901	97·763	108·626	130·351
274	54·512	65·414	76·317	87·219	98·121	109·024	130·828

No. of teeth.	1¼	1½	1¾	2	2¼	2½	3
275	54.711	65·653	76·595	87·537	98·479	109·422	131·306
276	54·910	65·892	76·874	87·856	98·837	109·819	131·783
277	55·109	66·130	77·152	88·174	99·196	110·217	132·261
278	55·308	66·369	77·431	88·492	99·554	110·615	132·738
279	55·507	66·608	77·709	88·810	99·912	111·013	133·216
280	55·705	66·847	77·988	89·129	100·270	111·411	133·693
281	55·904	67·085	78·266	89·447	100·628	111·809	134·171
282	56·103	67·324	78·545	89·765	100·986	112·207	134·648
283	56·302	67·563	78·823	90·084	101·344	112·605	135·125
284	56·501	67·801	79·102	90·402	101·702	113·002	135·603
285	56·700	68·040	79·380	90·720	102·060	113·400	136·080
286	56·899	68·279	79·659	91·039	102·418	113·798	136·558
287	57·098	68·518	79·937	91·357	102·776	114·196	137·035
288	57·297	68·756	80·216	91·675	103·135	114·594	137·513
289	57·496	68·995	80·494	91·993	103·493	114·992	137·990
290	57·695	69·234	80·773	92·312	103·851	115·390	138·468
291	57·894	69·473	81·051	92·630	104·209	115·788	138·945
292	58·093	69·711	81·330	92·948	104·567	116·185	139·423
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INDEX.

A

Adjustable gages, 38, 41, 42, 43, 49
Adjustable hand rest, 53, 56
“ plane for curves, 28, 32
Adjusting bevel square, 38

B

Babbitt metal, bearing for, 174, 175, 176
Bearing castings, shape of, 172
Bearing for Babbitt metal, 174, 175, 176
Bearing castings, contraction of, 172, 173
Bench stop, 166
Bench for pattern making, 166
Bench hook, 167
Bevel gage setting, 117
Bevel gear wheels, 206 to 213
Bevel pinion, 206
Bevel wheel, building up, 211
Bevel square, 38
Boiler, how to sweep up a, 193
Boiler, or pan, mold for, 193
Building pulley patterns, 133 to 142

C

Calipers, 49
Castings, contraction in cooling of, 99
Cement chuck, 65
Cement, mixture of, 65
Center plates, 58
Chisel handles, shape of, 34
Chisel, paring, 33
Chisel sharpening, 36
Chuck cement, 65
Chucking contrivances, 57
Chuck for thin work, 65
Chuck, methods of making, 59 to 63
Chuck screw, 64
Chuck wood faced, 59
Cog teeth for gear wheels, 225 to 233
Column patterns, blocks for, 178
“ “ cores for, 181, 182, 183
“ “ ornaments for, 181
“ “ how to make, 180
“ “ round, 184 to 188
Column patterns, square, 178
Compasses, 39
“ pencil attachment for, 40
Compass plane, 27
Contraction of brass castings, 172
Conversion of English inches into centimetres, 265
Conversion of centimetres into English inches, 266
Conversion of metres into English feet, 266
Conversion of English feet into metres, 266
Conversion of French square measure into English, 267
Conversion of French cubic measure into English, 267
Conversion of French lineal measure into English, 267
Cope of foundry flask, 74
Cores, use of, 82
“ kinds of, 83
“ for globe valve, 162, 163, 164, 165
Core boxes, 82, 83, 84, 85, 86, 87, 88, 89
“ boxes for T patterns, 130
“ boxes for pipe bends or T's, 146, 147, 148, 149
Core box plane, 30
Cores for pipe work, 90
“ sweeping for pipe bends, 149, 150

D

Decimal equivalents for avoirdupois weight, 268
Decimal equivalents for cubic measure, 261
Decimal equivalents for inches and fractions, 300, 301
Decimal equivalents for long measure, 268
Decimal equivalents for square measure, 261
Decimal equivalents for troy weight, 268
Diametral pitch, 270
Diameters, circumferences, areas, etc., of circles, 274 to 283
Diameters, areas, etc. of circles and contents in gallons, at one foot in length or depth, 297 to 299
Dog for holding work, 110
Dovetailed joints, 167
Dovetailing pinion teeth, 200

E

Endless screw, to cut in the lathe, 213, 214, 215
“ “ to cut by hand, 216 to 218

F

Face lathes, 61, 235, 236
Face plate, 59
Flasks for molding, 74, 75, 76
Fly wheels, calculating weight of, 249
Fore plane, how to use, 24
Foundry floor, 73
Foundry operations, 73 to 87, and 193 to 198
Fork center, 57

G

Gage hexagon, 116
Gages for sawing out cog teeth, 227, 228, 229, 230, 231, 232
Gages, 41, 42, 43
Gage, adjustable, 49
Gear wheel teeth, marking out, 201, 202, 203, 204
Gear wheel teeth cutting out, 204
“ “ “ frame for, 204
“ “ “ adjusting and fastening, 205
Gear wheels, bevel, 206 to 213
Gear worm screw, pattern for, 213, 214
Gear wheel patterns, construction of, 199 to 213
Gear wheel patterns made in sections, 205
Gear wheel patterns, solid pinions, 200
Gear wheel patterns, turning, 200
Gear wheel pinions, dividing off, 200
Gear wheel patterns, how to make, 199 to 213
Gear worm screw, cutting in the lathe, 214, 215
Gear worm screw, cutting by hand, 216, 217, 218
Gear wheel teeth, scale for, 218
Gear wheel teeth, how to use scale for, 219, 220
Gear wheels, patterns for, 199,
Gear wheel patterns, wood for, 200
Gear wheels, cog teeth for, 225 to 233
Gland patterns, how to make, 99 to 111, and 115 to 118
Gland patterns, kinds of, 92 to 98
Globe valve, 158 to 165
Gluing end wood, 123
Gluing segments, 137, 138
Glue pot, 243
Gluing wheel teeth, 205
Gouge turning, 66
Gouge, grinding a, 36
Gouge, concave and convex, 36
Gouge, how to hold, 66

H

Half lap joint, 168
Hand rest, fastening, 50, 51, 52, 53
“ “ movable tripod, 59
Hexagon brasses, bevels of, 172, 173
Hexagon gage, 116
Holding dog, 110
Holding turning gage, 66, 67
“ skew chisel, 68
Holes, marking, for pegging, 108

J

Jack plane, how to use, 24
Jig saw, 237, 238, 239
Joint, half lap, 168
Jointing spokes, 140, 141
Joints, tenon and mortise, 167
Journal, brass limits on patterns for, 99, 172, 173

L

Lathe for pattern work, 50
Lathes for facing, 63
Lathe, fastening rest upon. 50, 51, 52, 53
Lathe, cone pulley of, 55
Lathe rest, adjustable or movable, 56
Lathe, tailstock of, 56
“ running head of, 53
“ tools, 66, 67, 68, 69, 70, 71, 72
Lagging or staving, 190
Loam work, 193

M

Mallet, 47
Marking pin or peg holes, 114
Mitre box, 166, 169
Mitre joint, 169
Mixtures of metals, 250
Mixing varnish, 112
Molds, construction of, 73 to 81
Molding with sections of patterns, 222, 223, 224
Molding boards for thin work, 189
“ cores for columns, 191, 192
“ cored gland pattern, 94
“ cylinders by sweeps, 169
“ by section patterns, 221–224
“ cores for pipe bends, 149, 150
“ pulleys, 132
Mortise and tenon joint, 169

O

Oilstones use of, 23
Oilstones truing, 48
Oilstones kinds of, 47

P

Paring chisel, 33
Parallel strip, 46
Patterns for Babbitted boxes, 174 to 176
“ bearing boxes, 99
“ bevel gears, 206 to 213
“ bevel pinions, 210, 211
“ branch pipes, 126
“ columns, 178 to 184
“ cylinders, 197
“ glands, 93

Patterns for gear wheels, 199 to 207, and 225 to 234
“ globe valves, 158 to 162
“ pulleys, 132, 133, 134, 135
“ pillar block, 170, 174
“ pipe bends, 143
“ T's 120
“ window sill,
“ worm screw, 213 to 217
Patterns, sweep,
Patterns, loosening in the mould, 100
Pattern, varnishing, 112
Pegs or pins, 107, 108, 109
Peg or pin, making tool, 108
Peg, shape of, 109
Pitch, diametral, 270
Pin or peg holes, marking, 114
Planes, 20 to 32
Plane iron grinding, 20, 21
Planing machine, 242
Pulleys, patterns for, 132, 221
Pulleys, molding in sections, 222

R

Rabbit planes, 29
Rapping patterns, 78, 100, 101
Router plane, 28
Rubbers for sand-paper, 105
Rule to calculate thickness of cylinders and pipes, 248
Rule to calculate cylinders for hydraulic presses, 249
Rules to calculate weight of fly-wheel, 249

S

Sand-papering, 104, 105
Saw, band, 240
Saw, circular, 241
Saw, jig, 237, 238, 239
Scriber, 117
Screw-driver, 47
Screw chuck, 58
Section patterns, 223
Section molding, 222, 223, 224
Shape of chisel handles, 84
Shrinkage in castings, 244
“ bars, 245
“ cylinders, 244
“ disks, 245
“ general laws of, 246, 247
“ globes, 244
“ journal brasses, 245
“ ribs on plates, 247
“ table of, 245
“ tubes, 246
“ U-shaped castings, 246
“ wedge-shaped castings, 246
Shooting board, 137
Skew chisel, how to use, 68, 69
Staving or lagging, 151 to 157
Snap flask, 76
Spindle for sweep work, 139
Spokes, jointing, 140, 141
Square, 87
Steam cylinders, sweeping up, 196
Strength of cylinders, rules to calculate the, 248, 249
Swept cores, 149, 150
Sweep and loam work, 193
Sweep, operation of, 193, 194, 195, 196

T

Tables of weight, avoirdupois weight, 262
Tables of weight, troy weight, 262
“ “ of water, decimal equivalents for, 269
Tables of the weight of cast iron bars, 256
Tables of the weight of cast iron cylinders, 254
Tables of the weight of cast metals, 251
“ “ “ iron pipes, 252, 253
Tables of the weight of cast iron and lead balls, 254
Tables of the weight of copper bolts, 252
Tables of the weight of flat cast iron, 255
Tables of the weight of various kinds of wire, 257
Tables of the weight of nails and spikes, 254
Tables of the weight of water in decimal equivalents, 269
Tables of the weight of water in pipes, 259
Tables of the weight of water at different temperatures, 269
Tables of the weight of various substances, 256
Tables of the weight of ropes and chains, 255
Tables of the weight of timber, 251
“ “ patterns and castings, 251
Tables of the weight of metal plates per square foot, 258
Tables of Measure:
  Ale and beer measure, 263
  American and English measures, 261
  Comparative measures of length, 260
  Cloth measure, 260
  Dry measure, 261
  Foreign measures of length compared with U. S., 264
  Land measure, 260
  Measures of length, 260
  Miscellaneous measures, 261
  Nautical measure, 260
  Pendulums, 260
  Solid or cubic measure, 261
  Square measure, 261

Tables of Measure.—Continued:
  Timber measure, 302
  Wine measure, 263
Table of the sizes of drawing paper, 271
Table of the sizes of tracing paper, 271
" " iron washers, 273
" " penny nails, 271
" " taps for machine screws, 272
Table of the sizes of tapping holes for pipe taps, 272
Table of the sizes of sheet iron and zinc, 271
Table of the sizes of wire rope, 273
" diameters and number of teeth in wheels of various pitches, 308 to 320
Table of mixtures of metals, 250
" melting points of metals, 250
" squares, cubes, square roots, cube roots, etc., of numbers, 284 to 296
Table of diameters, areas and circumferences of circles, 274 to 283
Table of scantling and timber measure, 302 to 306
Table of natural sines, 307
" decimal equivalents, 265 to 269, and 300, 301
T pattern, 121
T pattern, core boxes for, 130
T pattern, how to make, 121 to 129
T pattern, skew, 126
Thickness for cylinders, 248
" " pipes, 248
" " hydraulic press, cylinders, 249
Thin patterns, 189
Timber drying, 17
Timber, selection of, 15, 16
Teeth, dovetailed, 212
Teeth of gear wheels, how to make, 200 to 210
Tools, bevel squares, 38
" block plane, 32
" boring, 72
Tools, chisels, 33, 34, 68, 69, 70, 71
" compasses, 39
" compass plane, 27, 32
" core box plane, 30, 31
" fore plane, 24
" for cutting endless screws or worms, 214, 215, 216
" gages, 36, 41, 42, 43, 49, 50
" gouges, 33, 34, 35, 66, 67
" jack plane, 20, 21
" jointer plane, 32, 33
" machine, 234 to 242
" parallel strips, 46
" plane blades, 20
" rabbet plane, 29
" router plane, 28
" smoothing plane, 32
" square, 37
" trammels, 44, 45
" trammel gage for T's, 125
" tool for pin making, 108
" turning, 71
Tripod hand-rest, 56

U

Useful numbers in calculating useful weights and measures, 264

V

Varnish, pot for, 112
" colors of, 113
" application of, 114

W

Wheels, making teeth for, 199 to 213, and 225 to 233
Wheel teeth dovetailed, advantages of, 210
Window sill, molding block for, 189
Window sill, pattern for, 189
Wire edge of tools, 23
Wood, facing chuck, 59
Wood, selecting, 15
Wood, shrinkage of, 18
Wood, storage of, 16
Wood, warping of, 17

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